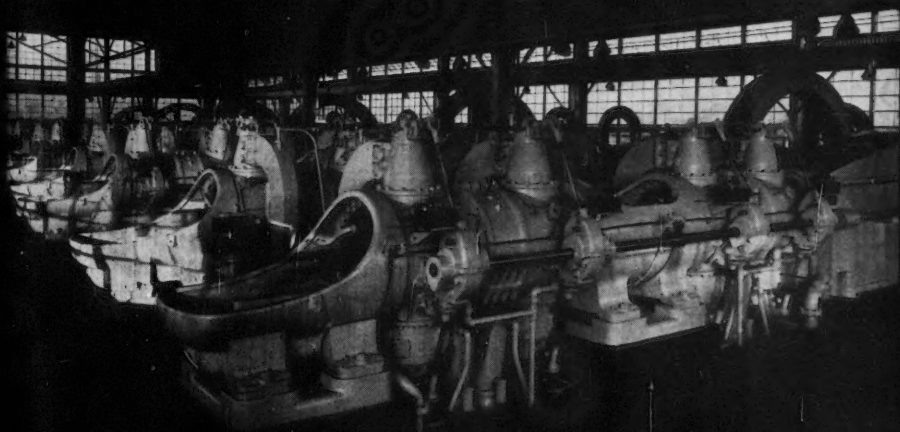


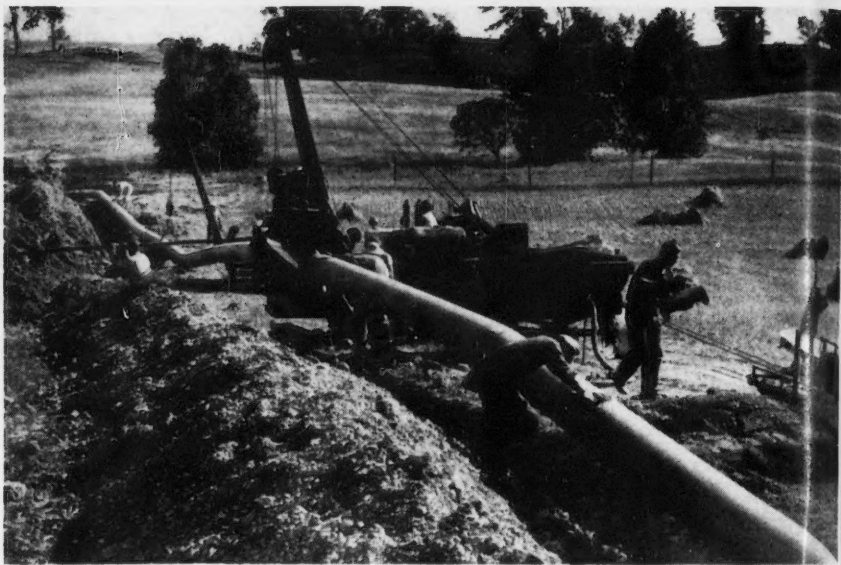
Corrosion

OFFICIAL PUBLICATION OF THE
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



October, 1949

15-10



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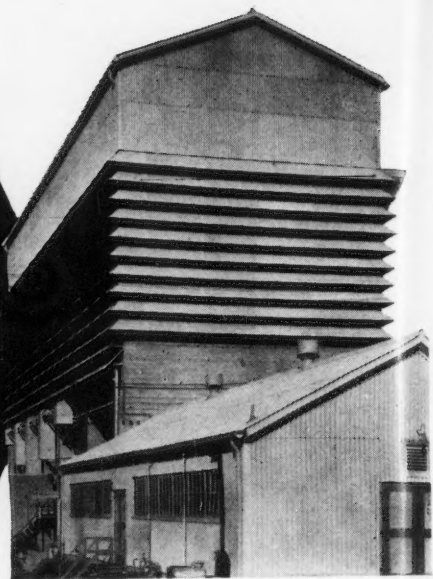
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VOLUME 4
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Corrosion

devoted entirely to

CORROSION

Research and Control

PUBLISHED MONTHLY AS ITS OFFICIAL JOURNAL, BY THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS, INC., AT HOUSTON, TEXAS, U. S. A., TO PROVIDE A PERMANENT RECORD OF PROGRESS IN THE CONTROL OF CORROSION AS DESCRIBED IN PAPERS PREPARED FOR THE ASSOCIATION AND FROM OTHER SOURCES.

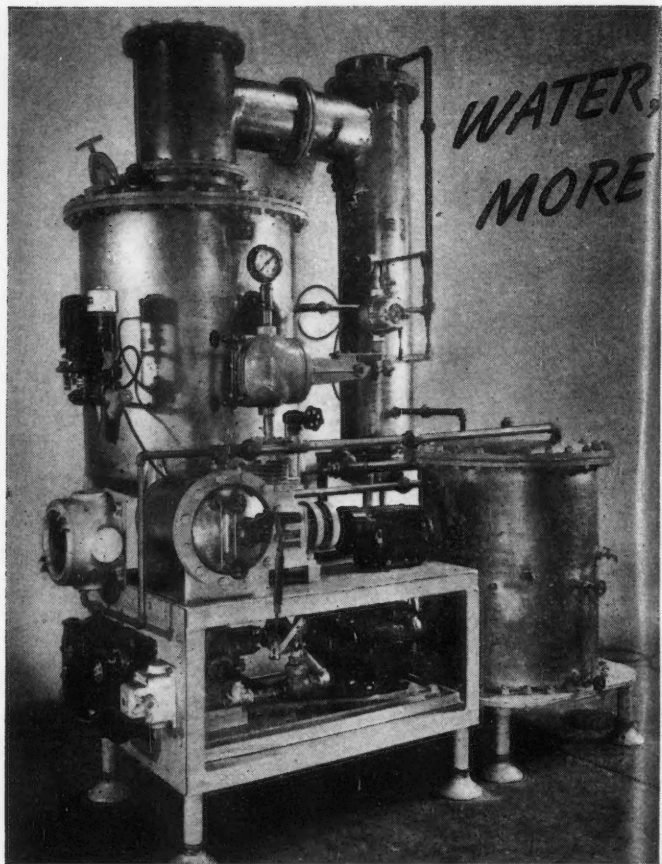


CONTENTS

| | |
|---|-----|
| Performance of Steam Condensers Aboard U. S. Naval Vessels By H. E. Bethon | 457 |
| Principles of Protecting Metals With Organic Coatings By A. J. Eickhoff and W. E. Shaw | 463 |
| Corrosion From Flue Gases By E. A. Rudolph | 476 |
| Fifteen Years' Experience in Application of External Corrosion Mitigation Methods to a High Pressure Natural Gas Transmission Line By N. K. Senatoroff | 479 |
| Selected Bibliography on Salt Spray Testing, 1935-1946 By Lorraine R. Voigt | 492 |
| A Message From Your Officers | xi |
| Topic of the Month | 1 |
| NACE News | 3 |
| Corrosion Abstracts | 9 |
| Index to Advertisers | 34 |

THIS MONTH'S COVER

• Interior of Tennessee Gas Transmission Co., Fostoria, Texas, Pumping Station. Tennessee Gas dehydrates the gas to prevent condensation of water, thus minimizing internal corrosion in installations of this type. External corrosion of piping, valves, and fittings is prevented by application of protective coatings and cathodic protection where necessary.



A MAN has been known to fall into a creek, come out soaking wet, and have the whole thing passed off as an accident. If it happens again he may fairly explain it as a coincidence, provided his other habits are good. But if a man falls into the water three times running, or more, he is evidently forming a habit which may be dangerous.

Similarly, water in raw materials repre-

sents a danger into which many chemical processes have fallen often enough to be termed a bad habit. The reasons are about as follows:

- (1) There is a close tie-up between water and many corrosion reactions.
- (2) Small quantities of water frequently intensify corrosion.
- (3) Water is almost universally present in raw materials to some extent.

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Logic would seem to dictate that in choosing materials to hold reagents that increase their corrosion rates markedly in the presence of unwanted water, one should select materials that can resist the aggression if it becomes necessary to do so. For instance, to choose an obvious example, sulfuric acid may absorb enough water from the atmosphere to become corrosive to iron or steel containers which are well able to withstand the effect of the concentrated acid. A number of good examples can also be drawn from halogenation processes. If all dry chlorination procedures were as completely dry in practise as they are on paper, many corrosion problems connected with them would be greatly alleviated. But in practice small amounts of water cannot always be prevented from accompanying some of the raw materials, and in certain cases water is inevitably formed as a result of the desired reaction.

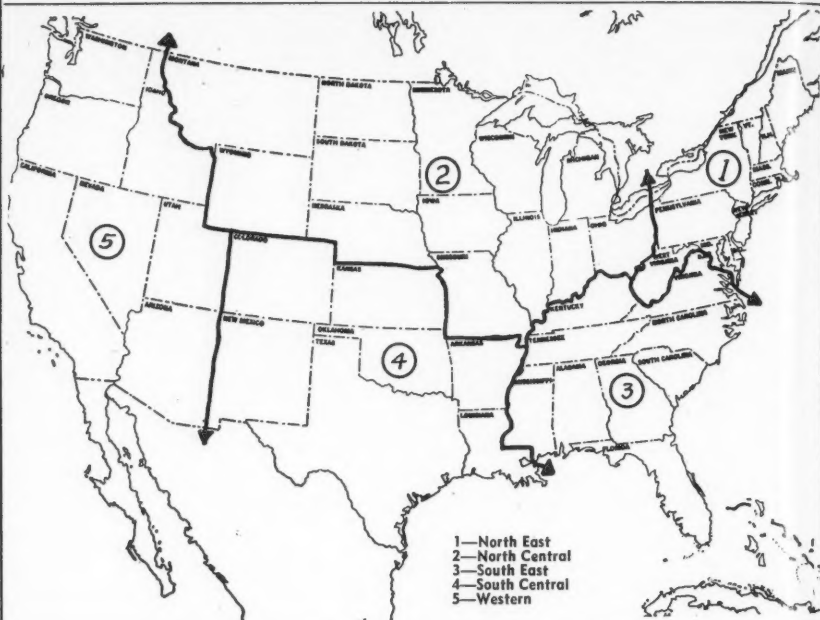
To prevent trouble from these sources, the user frequently finds it wise to install resistant equipment of nickel or nickel alloys. In many dry or nearly-dry processes for the manufacture of chlorinated products made in large volume, such as the chlorinated paraffins used for making detergents, the chlorophenols, perchloroethylene, trichloroethylene, phosphorus oxychloride, and insecticides of the DDT type, equipment made of nickel or Monel is in daily use and has met all requirements with satisfaction.

In the files of Inco's Corrosion Engineering Section are the tabulated results of many tests undertaken to study and alleviate such problems. We will be glad to make this information available to interested readers on request. Send for a copy of the *Corrosion Data Work Sheet*, which is designed to make it easy to report the essential factors.



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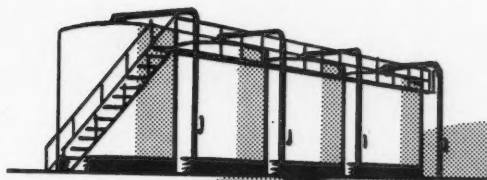
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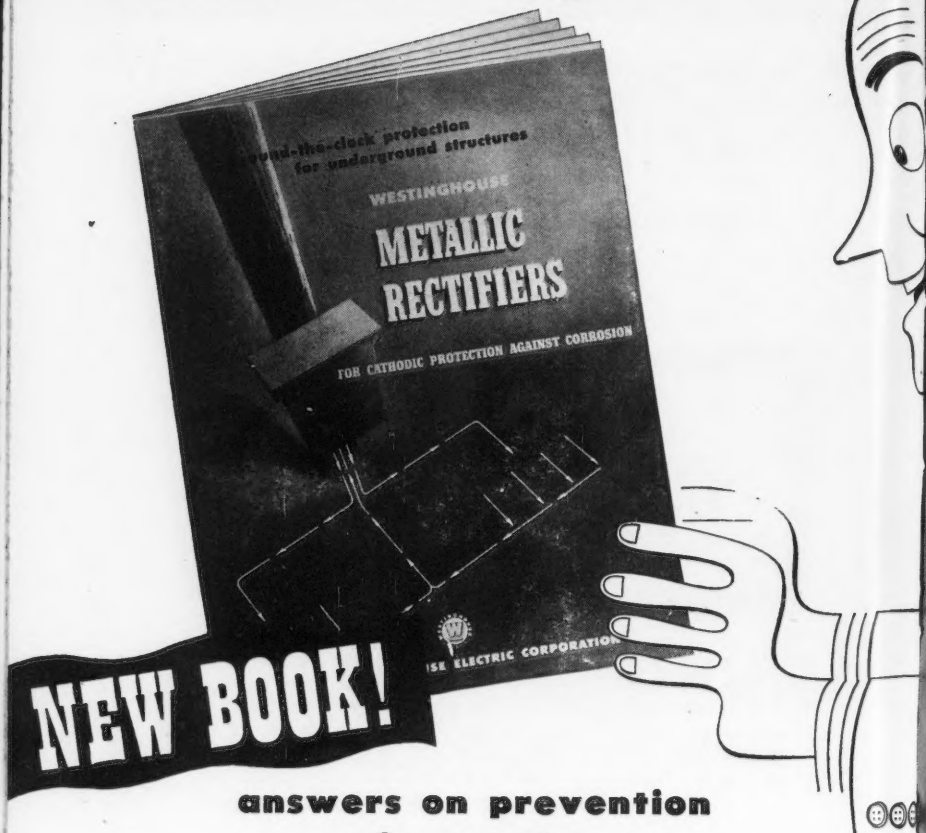
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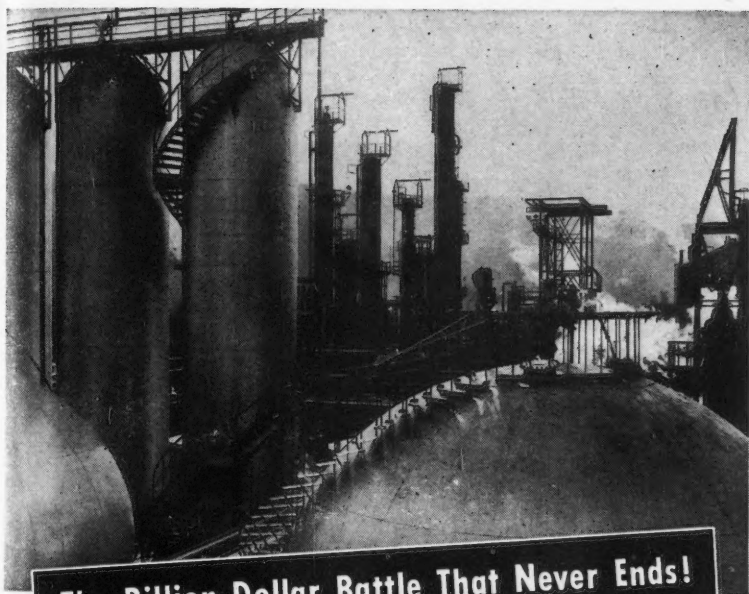


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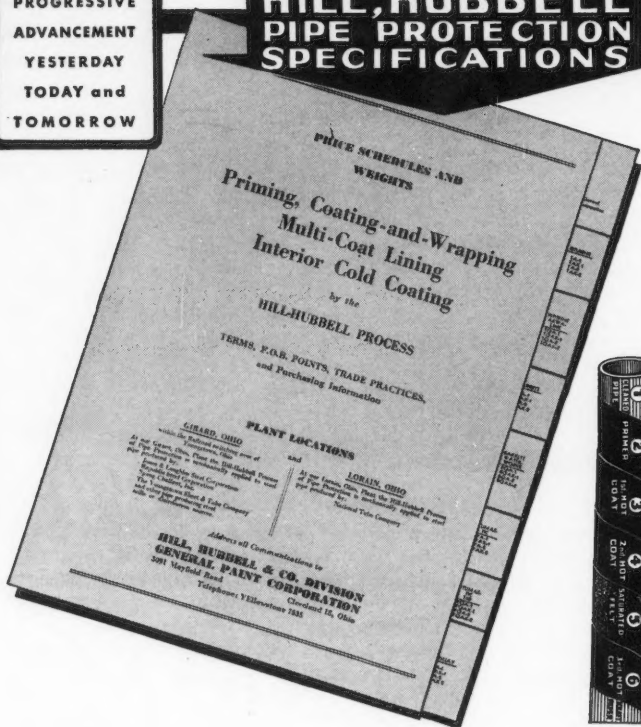
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A Message from Your Officers

By H. M. TRUEBLOOD, *Chairman*
Policy and Planning Committee



IN AN organization of human beings that is in a state of vigorous growth, whatever its announced objective, there is certain to be a ferment and jostling of ideas. This is a good thing, and should be recognized as such by all the members of the organization. It is a separate thing from the ideas themselves, any of which may be rated anywhere from worse than useless to excellent by different persons. But whether this state of affairs is regarded as good or bad, it must at least be accepted as a fact of nature in cogitating policies and formulating plans.

These agitations of thought and opinion lead to cohesions of ideas sufficiently similar for mutual accommodation. There is some wearing down of minor non-conformances to the average pattern in this process.

ess, but it is generally easy and painless. One must always expect to find a number of these sub-aggregates of opinion in any wide-awake organization. Their absence could not be taken as a sign of health.

But the bonds that unite them are equally necessary to the well-being of the organization, whose internal policies, with the plans for effectuating them, must be such as to prevent an undue relaxation of these bonds, without interference with the freedom of opinion to exert its due effect, and with the fundamental objectives of the organization always clearly in view. This is not a process that takes place naturally. It requires thought in planning and administration by capable and willing officers.

We have here, essentially, the problem of a democracy—never an easy one, and more difficult at a time when the organization is in rapid growth and a state of high activity. We are fortunate, in our Association, in having a fundamental objective which possesses powers both of attraction and of unification. In the pursuit of this objective, we have great elements of strength in the fact that industries as well as scientists and engineers are represented in our membership. We should not fail to utilize these advantages in pushing forward. We shall do well, also, to remember that the gift of compromise and the quality of good sportsmanship have been shown by history to be essential characteristics of successful democracies.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.



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Performance of Steam Condensers Aboard U. S. Naval Vessels*

By H. E. Bethon*

WE CAN BE thankful that this country emerged victorious from the most devastating war ever to be fought on this earth and that the time has come when the Navy can freely resume its peace-time scientific research investigations and studies in collaboration with industry.

The part played by the Navy in establishing beach heads, clearing the seas of enemy ships, transporting troops and supplies, constructing advance bases and maintenance of naval vessels aside from carrying the battle into enemy territory, especially in the Pacific, constituted a severe test of the efficiency and reliability of all types of naval vessels.

In time of war when naval vessels are required to operate at sea under full power conditions for prolonged periods of time, it is most important

to maintain the main and dynamo circulating water systems including the condensers in the most reliable and efficient condition possible. The necessity for a troop-carrying ship to forego its task assignment or to turn back to port when carrying a full complement of men and equipment on account of a leaky condenser tube is most serious. The disastrous results of losing the main condenser through tube leakage in the case of a single screw vessel cannot be over-emphasized. The necessity for securing a main propelling unit to plug a leaking tube may reduce a vessel's speed at a time when the safety of the vessel as well as other vessels operating in the same task force may be largely dependent on speed and maneuverability. The excellent service rendered by copper-nickel (70:30) tubes employed in the construction of all types of heat exchangers designed for salt water service, for example main and auxiliary condensers, distilling plants, lubricating oil and jacket water coolers, Freon-12 condensers, etc., was a deciding factor in assuring the suc-

* A paper presented at the Annual Meeting of NACE in St. Louis, Mo., Apr. 5-8, 1948.

* Principal Marine Engineer, Bureau of Ships, Navy Department, Washington, D. C.

Note: The opinions expressed herein are those of the author and do not necessarily represent the opinions of the Navy Department or the service at large.

cess of naval operations during the war. To date there has been no record of ever retubing a main condenser outfitted with copper-nickel tubes aboard a combatant vessel since 1933.

In 1933 the Bureau of Ships (formerly Bureau of Engineering) required the use of copper-nickel tubes and of naval rolled brass tube sheets in the construction of main and auxiliary condensers. The tube specifications existing at this time permitted a nickel content ranging from 19 to 32 percent and a zinc content of 6 percent maximum. As the result of many years experience with different condenser tube materials, the Bureau came to the conclusion that (70:30) copper-nickel presents the most satisfactory material from an all-around viewpoint.

In 1938 the Bureau modified its machinery specifications, not only for steam condensers but for all other salt water cooled heat exchangers, to require (70:30) copper-nickel tubes— $\frac{5}{8}$ -inch O.D. No. 18-BWG in thickness with a zinc content of 1.0 percent maximum, same material for the tube sheets and with designs based on a limiting tube velocity of 4.5 feet per second except in the case of the main condenser wherein 7.0 feet per second under full power conditions was permitted.

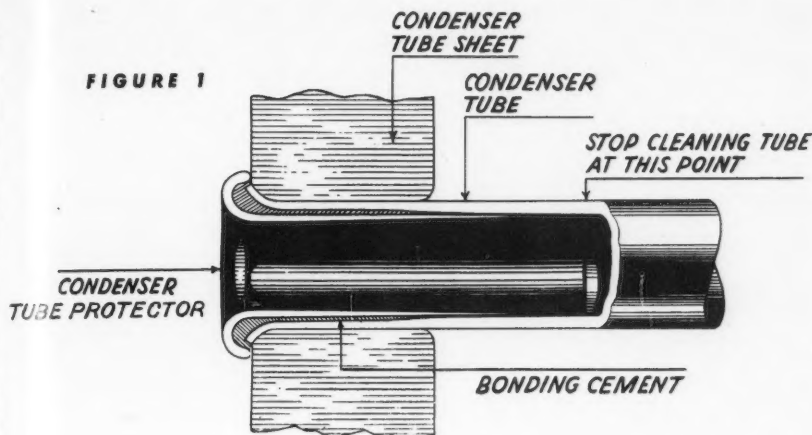
All main condensers provided with scoop injection are of single-pass construction whereas the majority of auxiliary or dynamo condensers provided with circulating pumps are of two-pass construction. The Bureau also required the use of welded sectionalized nickel-copper (Monel) water boxes for main condensers of

combatant vessels and of cast gun metal or valve bronze for auxiliary condensers and other types of salt water cooled heat exchangers. At the same time it was definitely established that the presence of nickel-copper (Monel) water boxes in a salt water circuit in contact with less noble metals comprising the tubes and tube sheets resulted in the rapid deterioration of the latter especially when the exposed area of the Monel water box was relatively large by comparison.

In order to retain the high tensile strength of Monel, which was important insofar as resistance to under-water explosion, the Bureau decided to require all Monel metal main condenser water boxes be wiped with solder (2 parts lead—1 part tin) to a thickness of $1/16$ inch which was reduced to a thickness between $1/32$ and $1/64$ inch during the war in order to conserve tin.

Failure of (70:30) copper-nickel tubes through plug or layer type dezincification, present in the case of brass tubes, is entirely absent in view of the negligible amount of zinc permitted by current specifications.

The improved fouling characteristics of (70:30) copper nickel over that of other metals is well recognized. Although the thermal conductivity of copper-nickel is considerably below that of Admiralty, the Bureau has established the fact that copper-nickel tubes in service for a reasonable operating period yield heat transfer rates at least equal to that of Admiralty tubes simply because of the fact that the scale formed on the copper-nickel tubes does not reach the proportions of



that for Admiralty, which is probably aggravated by the dezincification present in the case of Admiralty tubes.

During the war when vessels were operated at full power for prolonged periods it was found desirable to protect the inlet ends of (70:30) copper-nickel condenser tubes, which are admittedly softer than Admiralty or aluminum brass, from the severe erosion-corrosion effect of high velocity sea water saturated with oxygen and carrying entrained air impinging directly onto the tube ends. The erosion-corrosion action is greatly aggravated by the turbulence and air liberation existing in the vicinity of the approach to the inlet tube ends. For combating this destructive action the Bureau resorted to the use of plastic condenser tube inserts, about $2\frac{1}{4}$ inches long as shown in Figure 1 which are cemented into the inlet ends of the condenser tubes, after the vessel has completed its shakedown

trials in order to be assured that all tube joints were tight and free from leakage. Aside from affording protection to the inlet tube ends the presence of the plastic condenser tube inserts owing to their slight contraction in flow area, with no appreciable effect on flow through the condenser, will minimize the tendency of a foreign particle from becoming lodged in the tubes.

In order to improve the corrosion resistance and increase the hardness of (70:30) copper-nickel, the Bureau recently modified the tube and tube sheet specifications to require an iron content of 0.25-0.65 percent. otherwise the Bureau feels that the use of (70:30) copper-nickel with low iron and possibly aluminum (1.5 percent) content coupled with plastic condenser tube inserts will be a hard combination to beat especially for sea water service. Service experience has established that once sea water enters the inlet end and gets past the insert and flows longi-

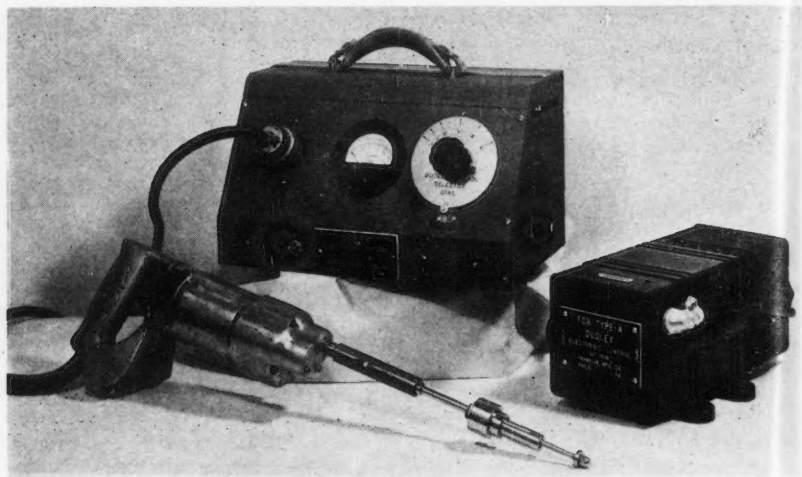


Figure 2—Electronic controlled tube expander.

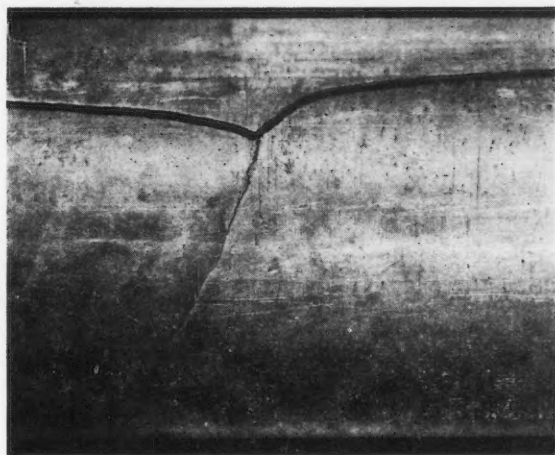
tudinal along the tube axis very little trouble, except in the case of an obstruction, will be experienced with tube deterioration.

Although there may be minor improvements made in the performance of condenser tubes arising from metallurgical changes, the Bureau feels that greater emphasis and more attention should be placed on the design and construction of the condenser, since it is recognized that the best tube from a material aspect will fail miserably when used in conjunction with a poorly designed condenser. The Bureau's experience indicates a preference for large main condensers packed at one end with approved flexible metallic packing, two fiber rings and two metallic rings alternately arranged with the fiber ring placed next to the tube sheet, since it has been established that tubes expanded at both ends are placed under an initial strain

either in compression, tension and/or torsion. In order to effect a more uniform holding power of the expanded tube joint and at the same time avoid any over-rolling and/or over-working of the metal the Bureau has developed an electronic controlled type tube expander as shown in Figure 2 which stops the tube rolling and expanding operation at a pre-determined point dependent on the diameter, thickness, material, etc., of both tube and tube sheet in question. Results with this type of tube expander in several naval shipyards have been most promising and the Bureau hopes to standardize on this tube expanding procedure or technique for all types of heat exchangers for shipboard installations.

Aside from inlet end erosion which has been successfully eliminated through the use of plastic condenser tube inserts, the types of tube fail-

Figure 3—Severely split aluminum brass condenser tube.



ures recently experienced in the case of (70:30) copper-nickel tubes aboard naval vessels that have been giving the Bureau considerable alarm are (1) obstruction attack, i.e., failure of condenser tubes due to the presence of foreign particles lodging inside the tube and (2) failure of tubes due to high velocity auxiliary exhaust steam, laden with moisture, impinging onto the outside of the tubes in cases where the internal baffling has not proved adequate. In the former instance the Bureau has developed a special air or motor driven rubber bladed type tube cleaner augmented by the circulation of sea water through the tube for flushing effect and has issued instructions to forces afloat and to naval shipyards that frequent examination of tubes should be made for tube obstructions, e.g., sand, fly-ash, mud, scale, slime, oil deposits, etc., and that tubes should be cleaned at frequent intervals by water lancing or by use of special devised tube

cleaners especially when the vessel has been operating in polluted areas. Care should be taken during these cleaning operations that no damage to the thin protective scale on the inside of the tube is incurred. In the latter instance the Bureau has paid particular attention to improving the baffling system so as to avoid impingement of moisture-laden steam onto the tubes and has issued instructions that excessive steam dumping into one main condenser should be avoided and that any condensation in the auxiliary exhaust system piping should be drained off through traps before opening up the line to the main condenser. In this connection it is anticipated that the "Probolog" or tube detecting device developed by the Shell Development Company will be employed to good advantage in determining the number of tubes in the vicinity of the auxiliary exhaust connection that are on the verge of failure, providing the situa-

bility of this device for copper-nickel tubes can be definitely assured.

The experience the Bureau has had with vessels built by the U. S. Maritime Commission for operation by the Navy as auxiliaries is outlined here briefly. In the majority of cases these vessels were outfitted with aluminum brass or Admiralty condenser tubes inasmuch as the War Production Board would not allocate copper-nickel tubes for these vessels in view of the scarcity of nickel, which was required in considerable quantity either alone or in nickel alloys for the Manhattan Project. The performance of the aluminum brass tubes under severe wartime conditions of operation was not very satisfactory. The Navy was called upon to assist in the emergency retubing of numerous vessels operating under the War Shipping Administration which were immobilized at sea because of condenser tube failures occurring on important war assignments.

The principle difficulty with aluminum brass was caused by the extreme brittleness that developed in the tube especially when expanded at both ends and when subjected to prolonged vibration, with the result that the tube would split either in a longitudinal or circumferential direction or both, longitudinal splits being as long as 20-30 inches. Figure 3 illustrates a severely split aluminum brass condenser tube. A tube opening up in this way was much more serious than a pin-hole failure as it contaminated the boiler feed system in short order. In most instances the initial split started in the immediate vicinity of the tube

support plate and extended in both fore and aft directions.

Aside from always maintaining strict vigilance over the proper operation and maintenance of steam condensers, the Bureau will be guided by the following major trend in connection with the future design of main condensers for naval vessels:

(a) Continue to employ $\frac{5}{8}$ -inch O.D. (70:30) copper-nickel tubes having low iron and/or aluminum content except with possible reduction in thickness from 0.049 to 0.035 inch and reduction in tube pitch in the interest of effecting a savings in weight and space.

(b) Continue to employ (70:30) copper-nickel tube sheets of same composition as the tubes.

(c) Continue to employ nickel-copper (Monel) water boxes of sectionalized type, wiped with a coating solder, of adequate depth and provided with air venting manifolds.

(d) Increase design tube velocity from 7.0 to possibly 10 or 12 feet/sec. under full power conditions.

(e) Continue to use plastic condenser tube inserts in the inlet ends of the tubes.

(f) Continue to prefer tubes expanded at the inlet end and packed at the outlet end with approved flexible metallic packing of 4-ring types.

(g) Employ electronic controlled type of tube expander for rolling the tubes into the tube sheet.

(h) Consideration of the advantages, if any, of continuing the installation of zinc or mild steel plates when similar materials are used in the hydraulic circuit.

Principles of Protecting Metals With Organic Coatings*

By A. J. Eickhoff* and W. E. Shaw*

TO PARAPHRASE the common expression,— “Never underestimate your enemy,” we might say— “Never underestimate corrosion.” At the slightest provocation, it is always ready to exert its destructive power. Much has already been said and written¹ about the enormous economic losses resulting from corrosion.

By definition, corrosion may be the result of one or more factors and is commonly understood as a gradual disappearance or disintegration of a metal through physical and chemical processes. A common example is the rusting of iron. Corrosion is essentially the formation of a more stable compound by the metal.

In our rapidly changing economy, a fundamental knowledge of corrosion and its control is becoming increasingly important. The obvious way to gain this knowledge is through research. Through the years, research has been responsible for the various theories to explain the mechanism of attack and account for the protection afforded. One by one, the various theories have failed to explain certain observations. As

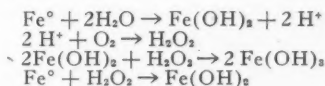
a result, they were discarded for a new one. At present, the electrochemical theory of corrosion is most commonly accepted.

Theoretical Considerations

Mechanism of Attack and Protection

Historically, many explanations for the mechanism of corrosion have been proposed. Of these, we can mention: (1) the peroxide theory, (2) the oxygen attack theory, (3) the alkaline theory, (4) the electrochemical theory.

The peroxide theory² was developed from evidences of peroxide formation during the corrosion of some metals. Iron has been used to describe the process in the following reactions:



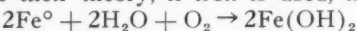
Some hydrogen peroxide³ has been found during the corrosion of copper, mercury, silver, lead, bismuth, tin and zinc. It has been reported as being present⁴ and absent³ when iron corrodes. However, many corrosion investigators have not been able to detect hydrogen peroxide in the presence of corroding iron. Such inconclusive data weaken

* A paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

* Research Laboratories, National Lead Co., Brooklyn, N. Y.

and destroy the peroxide theory. The presence or absence of hydrogen peroxide is explainable by the electrochemical theory and so this more inclusive theory can, of itself, account for observations leading to the peroxide theory.

The oxygen attack was stressed by Bengough and Stuart⁵ in their famous report in 1922. They emphasized the direct oxidation of the metal by dissolved oxygen. The chemical equation for an expression of their theory, if iron is used, is:



This theory fails to account for many known facts such as localization of corrosion and hydrogen evolution. Hence, it can be discounted.

Until recent data, the most widely held theory to explain the protection afforded to a metal by a paint film was the alkaline⁶ theory. This was postulated on a fairly well known fact that though a metal corroded rapidly in an acid solution, some degree of protection was offered by an alkaline solution. Natural waters that contain carbon dioxide from the air could be considered acid by the equation:

$\text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{H}_2\text{CO}_3$, and the corrosive reaction $\text{Fe} + \text{H}_2\text{CO}_3 \rightarrow \text{FeCO}_3 + \text{H}_2$. According to the equation, the carbonic acid would be readily regenerated by $4\text{FeCO}_3 + 10\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{Fe}(\text{OH})_3 + 4\text{H}_2\text{CO}_3$. Thus, the carbonic acid is set free and the cycle can repeat itself.

Inasmuch as most aqueous pigment slurries of the more widely used metal protective pigments are alkaline (red lead giving a pH of approximately 8.0) it could readily be inferred from the alkaline theory that the mechanism of protection was due

to the alkalinity of the pigment. However, it was demonstrated by Walker, et al,⁷ that corrosion will proceed in alkaline solution in the absence of carbon dioxide. Work done at the National Lead Company Research Laboratories⁸ in connection with the pH of distilled water in contact with pigmented paint films has shown that there is an initial high acidity with pH of 4.8 which gradually increases and approaches a pH of 6.2 in about two months. Even during this period, the metal is protected by the paint film from corrosion despite the fact that the water permeating the paint film is acid (See Figure 1).

Thus it can be seen that an alkaline environment is not necessary for the prevention of corrosion or corrosion would take place under the acid condition.

Electrochemical Theory

The most widely recognized theory for the explanation of corrosion is the electrochemical theory. It was proposed by Whitney⁹ and championed by many, notably Bancroft.¹⁰ Briefly, the theory states that corrosion is occasioned by the formation of two poles—an anode and a cathode. At the anode, the metal, iron for example, by virtue of its solution pressure, goes into solution as ferrous ion having lost two electrons in the process. These electrons flow through the metal to a cathodic area where they convert hydrogen ion to nascent hydrogen. This hydrogen may combine with itself to give hydrogen gas or with the oxygen in the surrounding environment.

Figure 2 illustrates the general mechanism of corrosion according to the electrochemical theory.

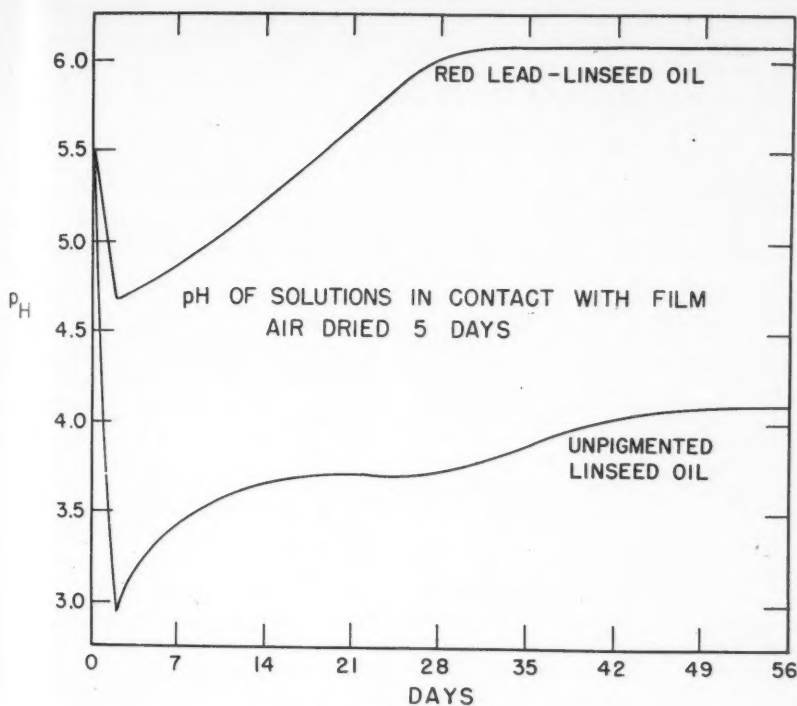


Figure 1—Time versus pH of water in contact with paint film.

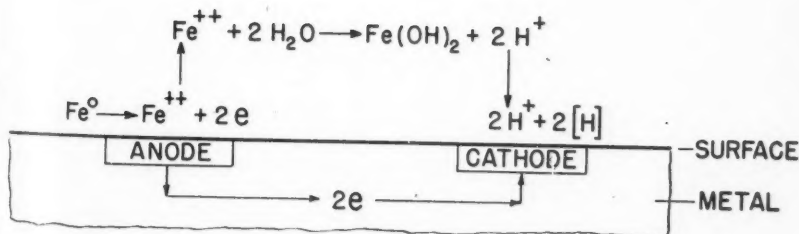


Figure 2—Electrochemical concept of corrosion of iron.

Figure 3 illustrates two substances with different solution pressures, iron and platinum. The iron at the anode goes into solution as the ferrous ion, releasing two electrons which travel through the external metallic circuit to the cathode where these electrons react with hydrogen ion to release nascent hydrogen. The external circuit is completed with a salt bridge or an electrolyte.

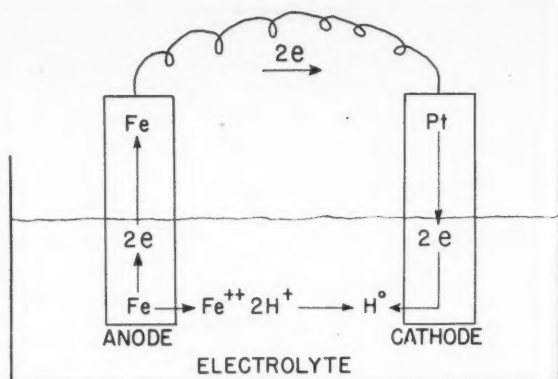


Figure 3—Corrosion of dissimilar metals in a uniform electrolyte (galvanic couple cell).

Figure 4 illustrates a concentration cell. With such a cell, corrosion will be accelerated at one electrode and retarded or stopped at the other. Because of the difference in solution potential of the two half cells, elemental iron could enter solution in the cell of lowest concentration. This releases electrons which will then flow to the iron electrode in the cell of higher concentration.

A practical illustration of Figures 2 and 3 is Figure 5, which shows a layer of mill scale on steel. In Figure 5, there are several types of corrosion cells, viz: (1) Concentration cell—

there is a variation in the concentration of oxygen in the moisture; (2) The combination of a metal and an oxide to give different solution pressures.

Many other causes of potential differences in metals are known. In the paper by R. B. Mears and R. H. Brown,¹¹ a table is given listing 18 possible causes. They are as follows:

1. Heterogeneity of the metal or alloy
2. Presence of grain boundaries
3. Difference in orientation of grains
4. Difference in grain size
5. Differential thermal treatment

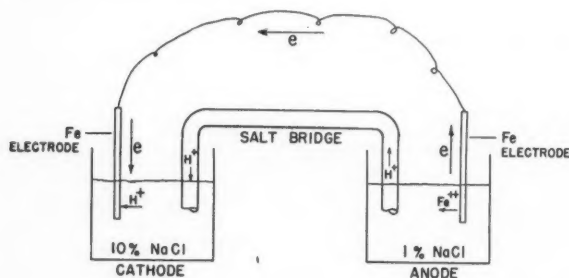


Figure 4—Corrosion attributable to variation in concentration of electrolyte (concentrated cell).

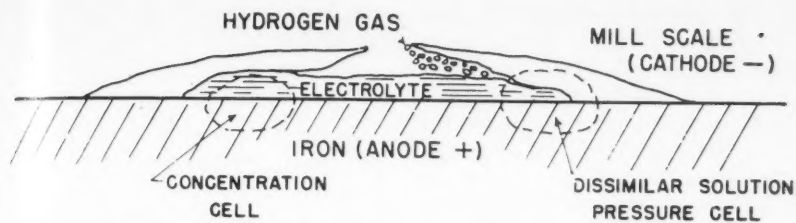


Figure 5—Corrosion of iron caused by variation in concentration of oxygen and metal-metallic oxide combination (complex cell).

6. Variations in surface roughness
7. Presence of local scratches or abrasions
8. Difference in shape
9. Differential strain
10. Differential pre-exposure
11. Differential concentration or composition of the corroding solution
12. Differential aeration
13. Differential heating
14. Differential illumination
15. Differential agitation
16. Contact with dissimilar metals
17. Externally applied potentials
18. Complex cells

To stifle or retard the processes of corrosion, either the anode or cathode must be blocked off. This can be done by the formation of insoluble primary cathodic or anodic products such as formed by the common inhibitors used in water treatment, also by the use of cathodic protection to oppose electronic flow. This mechanism may explain the protective behavior of paints. In other words, when the iron substrate starts to corrode, ferrous ions are released. These ions can combine with the hydroxyl ions in the water to form a somewhat insoluble fer-

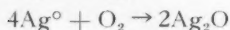
rous hydroxide. The solubility product of the hydroxide is relatively large so that free ferrous ions migrate away from the surface of the metal and are then oxidized to ferric ions which, having in combination with hydroxyl ions in the water a low solubility product, precipitate out. Now, if this insoluble film could be formed and maintained at the metal surface (anode), the anode would be stifled and further corrosion could not proceed. A pigment with a high oxidizing potential can do this and it can thus passivate the metal. With this type of protection, maintenance of a perfect paint film is not as mandatory as with a mechanical type of protective film.

Free Energy Concept

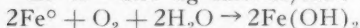
As a general concept, regardless of mechanism, it can be said that corrosion will take place whenever a decrease in free energy occurs between a metal and a possible reaction product. At present, no concept of rate is given by this type of treatment.

Some values of ΔF at 25° C. and atmospheric pressure which indicate the magnitude of the driving forces being encountered are indicated below.¹² ΔF may be defined as a meas-

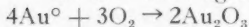
ure of chemical potential or free energy change.



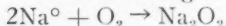
ΔF is -2.59 kg calories/mol.



ΔF is -115.7 kg calories/mol.



ΔF is 18.7 kg calories/mol.



ΔF is -105 kg calories/mol.

Dodge¹³ states that, for the purpose of ascertaining quickly and only approximately if any given reaction is promising at a given temperature, the following guide may be useful:

ΔF less than zero—reaction is promising.

ΔF greater than zero but less than 10.0 kg calories/mol—reaction is doubtful, but warrants further study.

ΔF greater than 10 kg calories/mol—very unfavorable, would be feasible only under unusual circumstances.

From these general criteria, it is obvious that the corrosion of gold is an "unfavorable" reaction. Whereas silver and silver oxide at room temperature are practically at equilibrium. Both sodium and iron are not in equilibrium with their corrosion products and can corrode readily.

Adhesion

For purposes of this article, adhesion is defined as the establishment and maintenance of a bond between the substrate and the paint film. This bond can operate by two distinct mechanisms. The first is mechanical—a keying of the paint film to irregularities in the substrate surface; the second is a mutual attrac-

tion of the substrate and the paint probably of an electrical nature.

The electrical forces may be of either the polar or ionic type, viz:

- (1) Dipole—induced dipole or mirror image dipole.
- (2) Ion—ion attraction—for example anodized aluminum provides good adhesion due to action of acidic constituents of the vehicle on the very adherent oxide coating.
- (3) van der Waals forces—for example adhesion of Johansson blocks.

A roughened surface provides a large number of pits and valleys to increase the effective area of the surface to be coated, allowing the electrostatic forces to be better utilized. According to Burns and Schuh,¹⁴ the sandblasting or mechanical roughening of a surface can result in at least a twenty-fold increase in the actual surface area per unit of microscopic area. The size of the grit also alters the contour of the blasted surface. The coarser the grit the greater the vertical distance between the peak and the valley.

By actual measurement, it has been found that the vertical distance from valley to peak on a sandblasted surface varies from 0.25 to 2.4 mils. with an average distance of 1 mil and the lateral distance from peak to peak varies from 2.5 to 4.9 mils. Figure 6 illustrates a cross-section of a sandblasted surface.

Adhesion is operative normal to the plane of the metal or parallel to its surface. Where rough contoured surfaces are available, mechanical adhesion is, or approaches a maximum limited by the shear

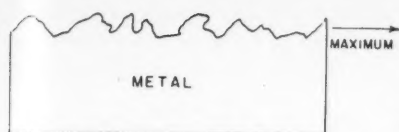


Figure 6—Idealized cross section of a sand-blasted surface.

strength of the film. A further limit on this maximum is occasioned by the ability of the paint to "wet" the surface and penetrate the crevices. For if "bridging" or poor wetting occurs, any possible mechanical adhesion would be lessened by the amount and degree of bridging. The degree of bridging is governed by the wetting ability of the paint on the steel. Figure 7 is a photomicrograph of a sandblasted steel surface.

By means of contact angle measurements,¹⁴ the wetting ability of substances can be estimated. It has been shown that unruined steel is organophilic. As soon as rusting begins, the surface becomes hydrophilic. In view of this instability, it is advantageous to paint a clean steel surface as soon as possible after cleaning. Figure 8 illustrates contact angles.

A phosphatized metal surface can be more easily wetted. Inasmuch as these converted surfaces are firmly adherent, the promoted adherence of the paint to the new surface will result in a greater

over-all adherence of the paint to the surface.

An examination of the electrical or polar forces at the metal-paint film interface is necessary to explain certain adhesion effects. The most active force involved is probably dipole-mirror dipole. Thus, the illustration in Figure 9 shows there are two attracting and two opposing forces, the attractive forces being of higher magnitude.

McLaren and Hofrichter¹⁶ state, "It has been shown that for an electrically conducting surface, the force of attraction of a dipole can be obtained by substituting in place of the surface a mirror image of the dipole in the surface (film) with the poles reversed." The value of the attractive force¹⁷ by which a dipole is attracted by its mirror image is

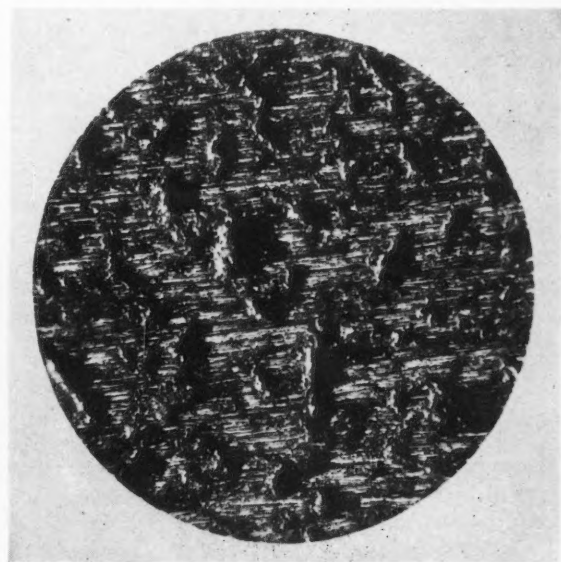


Figure 7—Photomicrograph of sandblasted surface (magnification 90X).

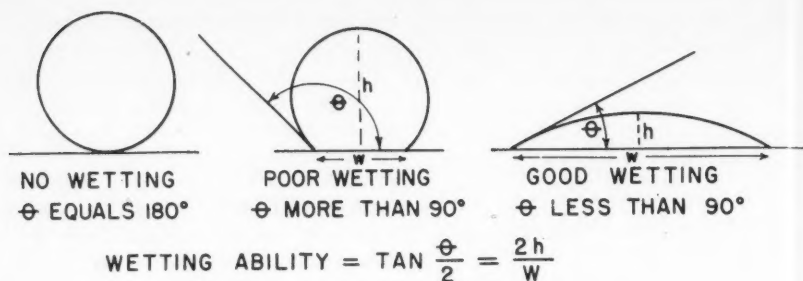


Figure 8—Wetting ability of paint by contact angles.

given by the charge on the dipole squared, divided by the dielectric constant.

Blistering

The blistering of paint films has been long a problem of particular importance, especially with regard to paints formulated to protect submerged steel surfaces. Water penetrates into the paint film at a greater rate than the reverse flow can take

place, causing a build up or pressure increase at the film-metal interface. Therefore blisters are occasioned by the preferential transfer of water through the semi-permeable paint film. As soon as the water dissolves some of the constituents in the film, osmotic effects occur. The membrane expands to accommodate the increase in volume occasioned by the osmotic effects. A potential gradient occasioned by electric currents or

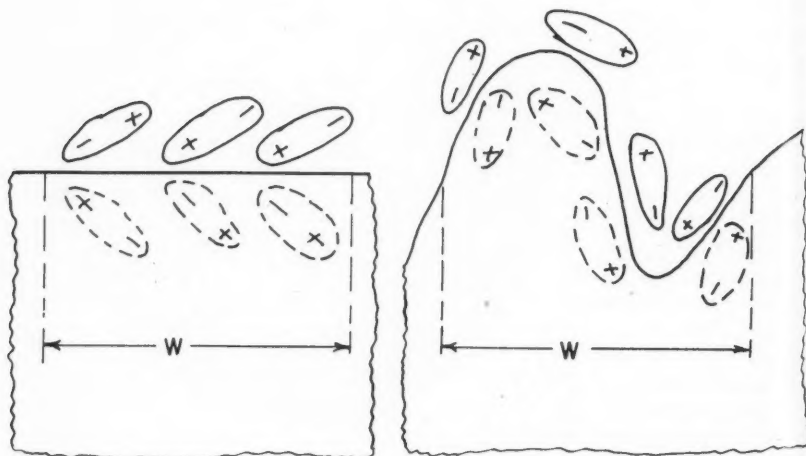


Figure 9—Dipole-mirror dipole forces on a plane and a sandblasted area.

corrosion potentials results in the same phenomena of preferential directional water flow (electroendosmosis).

This destructive force becomes visible in the form of small, raised spherical segments or blisters. Eventually, they unite to form a large single blister which is subject to easy removal, thus exposing bare metal.

Studies of the factors affecting blistering have been made by Kittleberger¹⁸ and by Kittleberger and Elm.^{19,20} From experimental data²⁰ they calculated that with linseed oil pigmented films, approximately 5 percent of water absorbed was due to osmosis and 95 percent was due to electroendosmosis. In these studies,^{19,20} "osmosis is defined as the transfer of water through a paint film under the influence of a solute concentration gradient; electroendosmosis applies to the movement of water through a film under the influence of an electrical potential gradient". The potential gradient was generated by the rapid corrosion of the bare metal anode, making the balance of the plate cathodic.

Kittleberger¹⁸ found that, in general, bare metal areas on the painted test panels increased the rate and degree of blistering of the paint coatings, and caused a decrease in the amount of rusting under the paint films as would be expected. However, occasionally there were reversals to this phenomenon. Water absorption and blistering were proportional to time of immersion but decreased with increasing osmotic pressure of the environmental solution.

The forces involved in lifting these

paint films from the metal surface have been estimated by the rather unique experiments performed by Kittleberger and Elm.¹⁹ Panels were immersed in solutions of sodium chloride or sugar having osmotic pressures from zero to 30 atmospheres (450 psi). The water absorption constantly fell off and approached asymptotically a value of approximately 3 percent, thus indicating that the osmotic pressures of the solution inside the paint film had values greater than 450 psi.

Practical Aspects

Surface Preparation

The question of how best to protect the enormous areas of iron and steel used in the varied processes of daily life is receiving considerable attention from both research workers and investigators in the field. Since there is almost no condition of practical use under which iron or steel does not rust, it is imperative that protective coatings be found which will better protect them from the corrosive elements.

The corrosion of steel has been labeled²¹ as "The Common Cold of the Steel Construction Industry." Rust and corrosion can always be avoided, provided one devises a means of furnishing adequate protection. Proper surface preparation is the first step in furnishing such protection. There are a number of methods from which to choose. Some are impractical to use after the steel has been erected. The more common methods of surface preparation are:

(1) *Weathering.* In most instances this is disastrous and to be avoided. Figure 10 indicates the rate of corrosion of partially corroded mill scale

surfaces subsequently painted. Such a practice results in a surface which has rust, pits, partially loosened mill scale, and moisture present.

(2) *Flame Cleaning.* This method makes use of the intense heat of the oxyacetylene flame which is rapidly passed over the steel surface. The temperature difference between the interior and the surface of the steel member sets up stresses which help remove semi-adherent mill scale. The high temperatures involved also dehydrate the rust. As a result, the surface is dry and warm. These two conditions are advantageous in promoting faster drying and better wetting by the paint.

(3) *Acid Pickling.* This method requires the use of hot aqueous solutions (5-10 percent of hydrochloric or sulfuric acid, or nitre cake, along with suitable inhibitors. Such a treatment leaves the desired clean surface for painting.

(4) *Sandblasting.* This method of descaling and cleaning steel make use of sand or steel grit or shot impinged on the surface by a stream of air at pressures of from 30 to 90 pounds per square inch. Often water is introduced to reduce the dust hazard.

Too much sandblasting can result in a surface with excessively deep crater-like depressions. The subsequently applied paint film may have inadequate thickness over the ridges, and these become focal points for premature failure, particularly if only one coat of paint is used. In addition, overstress caused by excessive working of the metal surface causes this area to assume a different potential than that of a neighboring unstressed area. This condition may accelerate corrosion if the pro-

TECTIVE organic coating is not applied soon after sandblasting.

(5) *Phosphatizing.* This process makes use of a hot or cold aqueous solution of metallic phosphates and phosphoric acid. Originally, the time for processing steel was from 45 minutes to 1 hour. Modifications of the chemicals have shortened the time to a few minutes. In this process, a tightly adherent metallic phosphate is formed at the surface of the metal and this promoted adhesion of subsequent paint films.

(6) *Cathodic Cleaning.* This process cleans metallic surfaces, partially or completely submerged in sea water, by means of a direct electric current of 0.03 to 0.40 ampere per square foot of cathode surface. The anodes may be iron or graphite. In the cleaning process, a coating is also formed. This cathodically formed coating consists of calcium and magnesium salts. By strict regulation of the current, one can control the ratio of calcium to magnesium and thereby control the characteristics of the deposit. When the current is turned off, the deposit of salts is slowly redissolved by the sea water. The details of this process are covered under U. S. Patent No. 2200469, dated May 14, 1940, and issued to George C. Cox. It is reported that this surface is suitable to receive paint even when these salts are present on the surface.

Metal Primers and Topcoats

Both our ancient and modern ways of life have placed considerable faith and reliance on the integrity of a thin, continuous film of paint. Until comparatively recent years, pigment and paint vehicle

manufacture was by rule of thumb and secrets were closely guarded and transmitted from father to son. However, during the past 30 years this industry has progressed from an art to a highly scientific business. Within the memory of most of us the finishing of automobiles, for example, has been shortened from weeks to a few hours.

Liquid paint is an intimate combination of pigment and vehicle with or without volatile thinner. When spread out in the form of a thin film, conversion from the liquid to the solid phase is the result of either the simple evaporation of the solvent or the more complex phenomena of oxidation and polymerization. In the final analysis the combination of primer and topcoat in addition to being adherent to each other must as a system strongly adhere to the base metal surface. The ultimate performance of the protective paint system will depend to an appreciable extent upon the adhesion.

Organic protective paint coatings generally comprise multiple films each of which is selected to perform certain functions. Briefly, the functions of the prime coat are to provide a tightly adherent base upon which

to apply subsequent paint coats, prevent corrosion of the base metal by the presence of a corrosion inhibitive pigment such as red lead, and to partially provide a barrier to the external corrosive environment.

In limited instances the primer can serve as both prime and finish coats, but usually a system is used in which the first two coats of paint contain a recognized corrosion inhibitive pigment dispersed in a vehicle suitable for the method of application and the environment to which the painted object is exposed.

Not all primers are sufficiently weather or chemically resistant to remain without a topcoat or to serve as the topcoat for prolonged periods. Therefore factors such as direct exposure to sunlight, moisture, resis-

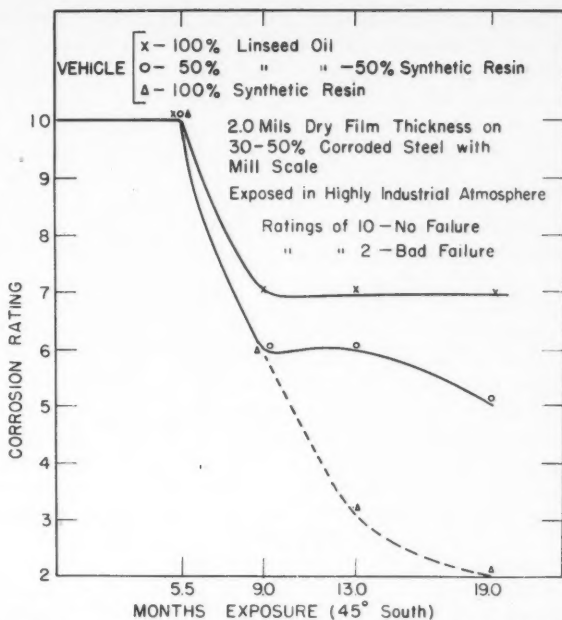


Figure 10—Protection afforded by paints of various wetting abilities.

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TECTIVE organic coating is not applied soon after sandblasting.

(5) *Phosphatizing.* This process makes use of a hot or cold aqueous solution of metallic phosphates and phosphoric acid. Originally, the time for processing steel was from 45 minutes to 1 hour. Modifications of the chemicals have shortened the time to a few minutes. In this process, a tightly adherent metallic phosphate is formed at the surface of the metal and this promoted adhesion of subsequent paint films.

(6) *Cathodic Cleaning.* This process cleans metallic surfaces, partially or completely submerged in sea water, by means of a direct electric current of 0.03 to 0.40 ampere per square foot of cathode surface. The anodes may be iron or graphite. In the cleaning process, a coating is also formed. This cathodically formed coating consists of calcium and magnesium salts. By strict regulation of the current, one can control the ratio of calcium to magnesium and thereby control the characteristics of the deposit. When the current is turned off, the deposit of salts is slowly redissolved by the sea water. The details of this process are covered under U. S. Patent No. 2200469, dated May 14, 1940, and issued to George C. Cox. It is reported that this surface is suitable to receive paint even when these salts are present on the surface.

Metal Primers and Topcoats

Both our ancient and modern ways of life have placed considerable faith and reliance on the integrity of a thin, continuous film of paint. Until comparatively recent years, pigment and paint vehicle

manufacture was by rule of thumb and secrets were closely guarded and transmitted from father to son. However, during the past 30 years this industry has progressed from an art to a highly scientific business. Within the memory of most of us the finishing of automobiles, for example, has been shortened from weeks to a few hours.

Liquid paint is an intimate combination of pigment and vehicle with or without volatile thinner. When spread out in the form of a thin film, conversion from the liquid to the solid phase is the result of either the simple evaporation of the solvent or the more complex phenomena of oxidation and polymerization. In the final analysis the combination of primer and topcoat in addition to being adherent to each other must as a system strongly adhere to the base metal surface. The ultimate performance of the protective paint system will depend to an appreciable extent upon the adhesion.

Organic protective paint coatings generally comprise multiple films each of which is selected to perform certain functions. Briefly, the functions of the prime coat are to provide a tightly adherent base upon which

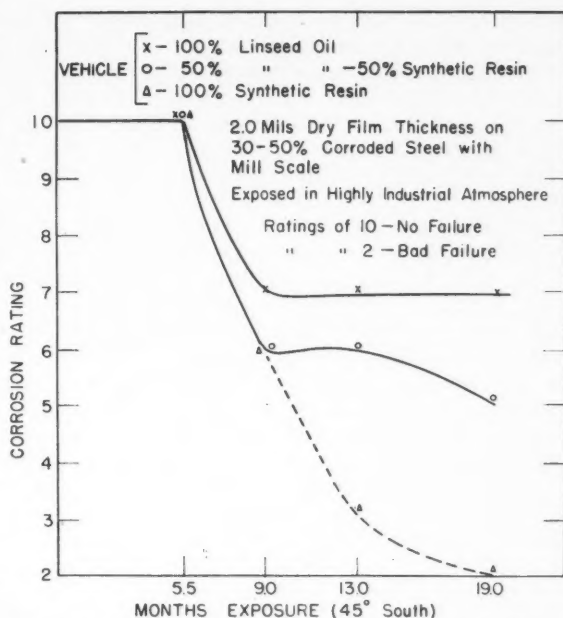


Figure 10—Protection afforded by paints of various wetting abilities.

to apply subsequent paint coats, prevent corrosion of the base metal by the presence of a corrosion inhibitive pigment such as red lead, and to partially provide a barrier to the external corrosive environment.

In limited instances the primer can serve as both prime and finish coats, but usually a system is used in which the first two coats of paint contain a recognized corrosion inhibitive pigment dispersed in a vehicle suitable for the method of application and the environment to which the painted object is exposed.

Not all primers are sufficiently weather or chemically resistant to remain without a topcoat or to serve as the topcoat for prolonged periods. Therefore factors such as direct exposure to sunlight, moisture, resis-

tance to acid, alkaline, saline, and other environments become important considerations. From many tests of metal paint systems, we have found that the performance of paint coatings must be regarded as a unit or system. In other words, not only must the individual paint coats comprising a system be selected for their function of combating the effects of corrosive environments, but they must be properly formulated to tenaciously adhere one with the other to prevent intercoat peeling, and they must acquire the proper degree of hardness within a specified time so that subsequent coats will not "alligator" or cause lifting.

A simple example of a properly selected system is one composed of two coats of red lead-linseed oil primer followed by a basic carbonate white lead-chromium oxide green-linseed oil topcoat. This system affords a high degree of protection to steel exposed to industrial or acidic atmospheres.

A system for steel structures immersed in fresh water such as river dams, water tanks, etc., which has proved very effective is one composed of a red lead-phenolic varnish paint.

For steel structures immersed in saline environments, an entirely new problem arises, such as ships' bottoms. In the case of underwater marine environments, the paint system is not only exposed to the sea water but also to the many species of marine organisms. The primer may be red lead incorporated in a highly water resistant vehicle. This must be followed by a suitable antifouling paint. Here too the general performance of the system is dependent upon the compatibility of

the primer and antifouling paints.

While the primer paint film shields the steel against external corrosive agents such as salts, acids, and moisture and the top coat paint film protects against abrasion, mechanical damage, and ultraviolet light, there may be some discussion as to just where each type of protection begins and ends. There is this difference however. When a paint coating contains an inhibitive pigment, the surface of the metal is altered due to the formation of a protective layer or barrier. As a result, the moisture impermeability of the primer is of secondary importance. This is pertinent since the existence of a completely impervious paint is questionable. On easily corrodible metals it has been found difficult to eliminate corrosive agents by the use of paints. In Whitby's²² experience "no paint, however successful on other materials, is impervious when applied to magnesium-base alloys and immersed in sea water or a chloride solution." Thus, while moisture exclusion is desirable, all metal protective paint coatings applied at practical thicknesses are nevertheless moisture permeable. Data published by Wilkinson and Figg²³ indicate that varnish films in water absorb 100 percent of their weight in fifteen days. Hence in choosing a metal protective paint, one should use an effective corrosion inhibitive pigment such as red lead in the primer coats to render the metal passive. The top coats should be designed to withstand the intended exposure environment and to provide maximum water resistance as well as protection against abrasion, mechanical damage, and ultraviolet light.

Summary

The realization of maximum protection of metal surfaces by means of organic paint coatings requires careful consideration of the following:

(1) Thorough cleaning and surface preparation so as to include the removal of all rust, moisture, and mill scale.

(2) Controlled composition of the paint with regard to non-volatile

vehicle, thinner and inhibitive pigment.

(3) Character of the base metal. Is it iron, aluminum, or galvanized iron?

(4) The environment to which the painted metal is exposed. Is it alkaline, acid, or saline?

(5) The degree of mechanical injury likely to be encountered.

References

1. J. C. Hudson, *The Corrosion of Iron and Steel*, p. 2, D. Van Nostrand, Inc., New York.
2. W. D. Bancroft, *Electrolytic Theory of Corrosion*, *J. Phys. Chem.*, **28**, 822 (1924) Aug.
3. W. R. Dunstan, H. A. D. Jowett and E. Goulding, *The Rusting of Iron*, *J. Chem. Soc.*, **87**, 1548-1574 (1905).
4. Traube, Moritz, Ber., **15**, 2434 (1882).
5. G. D. Benbough and J. M. Stuart, Sixth Report of Corrosion Research Committee of Inst. of Metals, on Nature of Corrosive Action and the Function of Colloids in Corrosion, with an Appendix on Terms Used in Colloid Chemistry, *J. Inst. Metals*, **28**, 31-144 (1922).
6. H. A. Gardner, *Metal Protective Paints*, *Trans. Amer. Electrochem. Soc.*, **39**, 223-225 (1921).
7. W. H. Walker, et al, *The Corrosion of Iron and Steel*, *J. Amer. Chem. Soc.*, **29**, 1251-1264 (1907).
8. W. E. Shaw and D. L. Hawke, unpublished data.
9. W. R. Whitney, *The Corrosion of Iron*, *J. Amer. Chem. Soc.*, **25**, 395 (1903).
10. W. D. Bancroft, *Electrolytic Theory of Corrosion*, *J. Phys. Chem.*, **28**, 785-871 (1924) Aug.
11. R. B. Mears and R. H. Brown, *Causes of Corrosion Currents*, *Ind. & Eng. Chem.*, **33**, 1001 (1941).
12. W. M. Latimer, *Oxidation States of the Elements and Their Potentials in Aqueous Solution*, Prentice-Hall, New York.
13. B. F. Dodge, *Chemical Engineering Thermodynamics*, p. 498, McGraw-Hill (1944).
14. R. M. Burns and A. E. Schuh, *Protective Coatings for Metals*, pp. 313-315, Reinhold Publishing Corp., New York.
15. N. F. Miller, *The Wetting of Steel Surfaces by Esters of Unsaturated Fatty Acids*, *J. Phys. Chem.*, **50**, No. 4, 300 (1946) July.
16. A. D. McLaren and C. H. Hofrichter, Jr., *Theory of Adhesion of High Polymers to Cellulose*, *Paper Tr. J.* **125**, No. 19, 96 (1947).
17. W. L. H. Moll, *A Study of the Dielectric Constant, Polarization, and Dipole Moment in Colloidal Systems*, *Kolloid Zeitschrift*, **76**, 200-210 (1936).
18. W. W. Kittleberger, *Water Immersion Testing of Metal Protective Paints*, (Influence of Bare Metal Areas), *Ind. & Eng. Chem.*, **34**, 943 (1942).
19. W. W. Kittleberger and A. C. Elm, *Water Immersion Testing of Metal Protective Paints* (Role of Osmosis in Water Absorption and Blistering) *Ind. & Eng. Chem.*, **38**, 695 (1946).
20. W. W. Kittleberger and A. C. Elm, *Water Immersion Testing of Metal Protective Paints* (Role of Electroendosmosis in Water Absorption and Blistering), *Ind. & Eng. Chem.*, **39**, 876 (1947).
21. Enoch R. Needles, *Proc. of Oct. 17, 1940 Mtg. at Annual Conv. of Amer. Inst. of Steel Construction*.
22. L. Whitby, *J. Oil & Colour Chem. Assoc.*, **16**, 411 (1933).
23. J. A. F. Wilkinson and E. F. Figg, *J. Oil & Colour Chem. Assoc.*, **7**, 241 (1924).

Corrosion from Flue Gases*

By E. A. Rudolph*

IT IS REASONABLY accurate to say that engineers have two approaches to the typical metallic corrosion problem. One, apply a suitable inhibitive or protective coating to the surface subject to corrosion. Two, use an alloy or metal resistant to corrosion in the atmosphere in which it is required to serve. The two solutions have overlapping fields. For example, galvanizing is a form of a protective and inhibitive coating of corrosion resistant metal or alloy.

Recently, the Union Electric Company encountered a corrosion problem which, because of temperature conditions, was not subject to the first treatment of a protective coating, and because of the cost did not lend itself to solution by substitution of a corrosion resistant material. The problem was the corrosion to the point of complete failure of the housing for electrostatic precipitators which are installed between the boilers and the induced draft fans in several power plants.

Stack gases from coal-fired boilers are very highly corrosive when they are accompanied by a condition providing sufficient moisture for corrosive chemical action. Under proper firing conditions the gases will contain from 12 to 14 percent carbon dioxide, and may contain as

much as 0.4 percent of sulfur dioxide depending on the sulfur content of the coal burned. There is also an excess of free oxygen present. Under certain conditions in high temperature boilers, the sulfur dioxide may be raised to sulfur trioxide by combining with the free oxygen. Thus, we have present the anhydrides of two weak acids, carbonic and sulfurous and possibly one strong acid, sulfuric, all highly corrosive.

There is also present in the stack gases from 7 to 8 percent of water vapor from the evaporated moisture of the coal and the combustion of the hydrogen in the volatile hydrocarbons in the coal. All that remains to be done is to condense the water vapor and we have corrosive agents ready for the attack.

In the case of the precipitator housings, protective coatings of an ordinary nature are not practical as corrosion preventives because of the high temperature of the gases (about 400° F. and above) and abrasive action of the solids (fly ash, fine cinders, etc.).

In the past, attempts have been made to prevent corrosion by the application of concrete coatings applied by a cement gun and held to the surface of the duct chambers by anchorage of wire mesh attached to the duct wall by welding or similar arrangement. In the case of precipitators, however, where the exposed area was rather large, it

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* Mechanical Operating Engineer, Steam-Electric Plants Dept., Union Electric Co. of Missouri, St. Louis, Mo.

was found that cracks developed in this concrete protective casing and permitted the stack gases to come in contact with the metal. At periods when the outside temperatures were low, this metal casing would be so reduced in temperature that the moisture in the stack gases would be condensed on the surface of the metal and corrosion started at once.

Since the application of a corrosion-resistant coating in contact with the stack gases failed, a different approach was adopted and has been found wholly successful. The procedure was to apply the preventive in the form of a thermal insulating coating or blanket to the surface of the duct exposed to ordinary atmospheric temperatures. This prevented the radiation of heat to the atmosphere and made it possible to hold the metal of the precipitator chamber at a temperature above the dew point of the stack gases. This insures that there will be no condensation on the metal surface in contact with the stack gases at any time.

Another aspect of the corrosive action of the stack gases in the presence of moisture was illustrated by the repair work made necessary on the stacks at the Cahokia plant when rain and water and stack gases were able to reach the reinforcing steel in the concrete core of tile-faced reinforced concrete chimneys. This was particularly noticeable at the tops of the chimneys, which are 260 feet high. In some cases, one-half inch square reinforcing bars were completely corroded away and in many places reduced to 25 percent of their original cross sectional area. The increase in the volume of the products of corrosion as compared to the

original steel was such that the concrete core was ruptured by the expansion and the tile facings displaced to such a degree that ten feet had to be removed.

The whole problem of corrosion of power plant equipment by flue gases is discussed in Bulletin No. 228 of the Engineering Experiment Station of the University of Illinois.

Discussion

By G. C. Daniels*

The corrosion problem due to flue gases as covered in Mr. Rudolph's paper is present in most steam power plants. At one time, it was the practice of our company to insulate the inside of all breechings by first applying an adhesive cement covered with insulating blocks, then a layer of expanded metal which was fastened to the steel plate by means of welded-on studs, and over this a layer of abrasion-resisting insulating cement. Under the roof line this construction has been very satisfactory and is still being used, but above the roof line the heads of the bolts corroded away rather rapidly even when Ithrigized bolts were used. Cracks also developed in the insulation and caused corrosion of the steel plates underneath the insulation and as a result the insulation fell off.

Tests were then made to determine if Transite covering applied to the outside of the stiffener channels of the breechings would provide sufficient insulation to keep the breeching metal temperature high enough to prevent condensation, and it was found that the metal temperature

* Chief Mechanical Engineer, The Commonwealth & Southern Corp., Jackson, Mich.

was only a few degrees cooler than the flue gas temperature except where the stiffener channels were fastened on to the breeching.

By laying an extra thickness of Transite between the stiffener channel and the Transite covering, sufficient insulation was obtained. Breechings covered in this manner need no painting or maintenance work and present a good appearance, and the cost is less than inside insulation and not materially different from the cost of guniting.

It had been the previous practice of our company to line our concrete stacks for their entire height with a hard-burned brick set in acid-resistant mortar composed of fine silica sand and sodium silicate. We found that some of the brick linings cracked and undoubtedly flue gas came in contact with the concrete shell so that the lining gave less protection than expected. After a recent survey we have concluded that unlined concrete stacks would be satisfactory for our flue gas temperatures, which range from 320° to 360° F. We have torn down a number of concrete stacks that were lined only one-third of the way to the top and have found them to be in good condition after many years of service. We believe that if good dense concrete is obtained and cured with water flowing over the surface for a week's time to get a good cure, the danger from corrosion will not be very great.

It is interesting to note that the author of this paper experienced trouble with gunite coatings on large flat breeching surfaces due to cracks developing, which ultimately resulted in corrosion of the steel plate be-

neath. The practice of guniting the interior of steel stacks and breechings is becoming rather prevalent and more data on the experience with this type of protective coatings would be valuable.

Discussion

By R. T. Roberts*

We had corrosion in the upper housings of East River precipitators. We remedied that by putting in warm dry air at higher pressure than gas to force leakage into the gas stream.

Referring to insulation on the outside of the precipitator to prevent internal corrosion:

1. If the insulation leaks through cracks due to any cause, severe corrosion will occur externally and be just as detrimental as internal corrosion. (We were forced to take all insulation off the flues at Hudson Avenue for this reason. At Hell Gate, catch basins formed by the stiffeners caused corrosion and to prevent this we drained the spots by drilling holes in stiffeners.)

2. It is expected that some internal corrosion would occur even with insulation as described. Ash will stick to all surfaces, and during outage, due to the hygroscopic nature of the ash, will absorb moisture and thus effect corrosion on the plates.

3. We have used nitro-seal as a protective coating on flues with good results, if applied correctly. It will stand much higher metal temperatures without deterioration than lead base and oil paints.

* Mechanical Engineering Dept., Consolidated Edison Co., of New York, Inc., New York, N. Y.

Fifteen Years Experience in Application Of External Corrosion Mitigation Methods to a High Pressure Natural Gas Transmission Line*

By N. K. Senatoroff*

LONG DISTANCE, high pressure transmission of natural gas as we now know it, had its rapid expansion in the latter part of the twenties, as a result of application at that time of a new electric welding technique to mass production of steel pipe, which in turn allowed the use of higher stresses in design of pipelines.

The gradual decrease in wall thickness of the pipe and utilization of higher wall stresses introduced, however, greater corrosion hazards, external and internal, into the heretofore well established operating and transmission practices of the gas industry. The failure of a long high pressure transmission line constituted no longer only the inconvenience of repairing the break or the leak, but in many cases the necessity

of a prolonged line shutdown with a danger of creating fuel shortage to the industry or to a populated area and the existence of much greater fire or explosion hazards in case of a failure occurring in a city.

The foregoing rapid changes in natural gas pipeline design prompted a quest on the part of pipeline operators for better understanding of corrosion phenomenon and a search for dependable methods of its control.

It was very fortunate for the natural gas industry to find that extensive studies of underground corrosion and its prevention were under way just prior to this time by the United States Bureau of Standards, the American Gas Association, the American Petroleum Institute and numerous universities in this country and abroad. The reports of the activities of the underground corrosion sections of the various committees and the results of their findings

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*Chemical Engineer, Southern Counties Gas Co. of California, Los Angeles, Calif.

just began to appear in current technical literature to serve as a guide in providing the necessary information on the general subjects of corrosion surveys, testing and its control. Such papers as (1) "Pipe Line Currents and Soil Resistivity as Indicators of Local Corrosive Soil Area," (2) "Methods for Estimating Corrosiveness of Acid Soils in Contact with Iron and Steel Pipe," (3) "Soil Survey Methods Are Essential Part of Any Corrosion Survey," and many others became the veritable text books for engineers engaged in pipeline corrosion protection work.

In the paragraphs that follow, are some of the then current methods of soil corrosion surveys and coating specifications which were applied to the Huntington Beach to San Diego natural gas transmission line at the time of its design and construction.

In "Conclusions," are given evaluations of their performance as corrosion preventive measures after 15 years of service and standardization of coating specifications for current pipe protection work.

In enumerating the several pipeline anti-corrosion methods which were tried and applied to this line, successful performers, and those which resulted in failure are listed.

Considering the rapidly expanding period during which this line was built and taking into account also the meagerness of actual "performance" experience of some of the newly devised corrosion mitigation methods which were used, it was evident from the start that a number of failures would occur due to the probable limitations of some of the mitigation methods tried,

Huntington Beach to San Diego Pipeline

The Huntington Beach-San Diego line is 12¾-inch O.D. electric fusion weld pipe, approximately 80 miles in length, 68 miles of which were installed in 1932 and 12 miles in 1929. The pipe ranges in weight from 33.75 pounds to 81 pounds per lineal foot.

The line for the most part follows the Pacific Ocean coast line, traversing a variety of soil types, making submarine crossings and passing through tightly built-in towns. Several miles of the line are located on the shoulder and under the pavement of a heavily traveled highway. Occasionally, it crosses agriculturally developed lands, which are periodically deeply irrigated. The extreme variation in soil types, conducive to severe external corrosion of bare steel, brought forth the need for a careful soil corrosivity survey for its entire length.

The soil corrosivity data obtained by the survey were subsequently used in the selection of pipe coating materials and the location of cathodic protection stations.

Special importance was attached to the selection of the most effective means of corrosion control because the line constituted the only supply of natural gas to the City of San Diego.

Soil Survey

At the time, prevailing tendency in the protection of pipelines against soil corrosion had been towards application of protection to only those sections of the line which traversed "hot spots," omitting protection through areas of high resistivity

TABLE I
Soil Types and Resistivity—Corrosivity Relationship

| TYPE OF SOIL | Map Color | Descriptions | Rod Readings Ohms | Estimated Life of Bare Steel, Years |
|--------------|-----------|--------------|----------------------|--|
| 1..... | Green | Excellent | 10,000-6,000 | 25 or more |
| 2..... | Blue | Good | 6,000-4,500 | 17-25 |
| 3..... | Brown | Fair | 4,500-2,000 | 10-17 |
| 4..... | Red | Bad | 0-2,000 | 0-10 |

soils. Our company followed the same practice. Since such areas could not be identified from surface topography or by means of visual inspection of the soil, the location of "dangerous" areas by other means became imperative. The search for such means was centered on a study of Research Paper 298 by E. R. Shepard, Bureau of Standards, entitled, Pipe Line Currents and Soil Resistivity as Indicators of Local Corrosive Soil Areas.¹

Because of the extreme simplicity in handling and of greater speed with which desired soil resistivity readings could be obtained and also due to the proved existence of an approximate relation between corrosivity and resistivity of western alkali soils it was decided to conduct a soil survey of the entire pipeline with the aid of "Shepard Rods."

Preliminary survey of the pipeline route was conducted by taking soil resistivity readings at 500-foot intervals at a depth of approximately 24 to 28 inches and not necessarily along the actual right of way, because of pending agreements with property owners.

The final soil resistivity readings were taken at the bottom of the excavated ditch and were used for the selection of coating materials and for the posting on the maps of the accurately established pipeline stations.

Color designations corresponding to the resistivity range of several soil types were worked out for the route for the purpose of providing at a glance color picture of soil corrosivities through which this pipeline was laid.

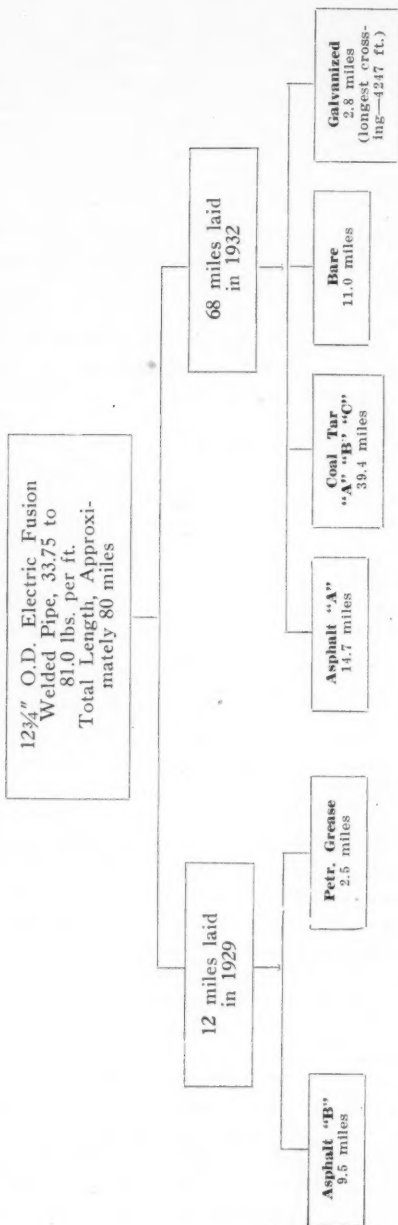
Soil Types

Since the proposed line would be the first line to be installed along this route, no "leakage" history from the records of some older paralleling line were available; the engineers had to use the soil resistivity data from the survey by means of correlation of soil corrosivity to its resistivity that had been established for alkali soils elsewhere on the Gas Companies' systems and to classify the soils along the new route in terms of corrosion experience gained on other pipelines. Based on this experience, all soils were grouped into four classes. Table I shows the correlation used on the line which was previously established for the entire Southern Counties Gas Company System. Table II contains accumulated mileage of various coatings applied on the line.

Protective Coatings

After having classified into four types all soils encountered along the line, the questions of coating specifications and selection of coating materials were simplified and nar-

TABLE II
Mileage and Type of Coatings Used on Huntington Beach
to San Diego Pipeline



rowed down to the following types:

(1) *Coal Tar Protective Coatings*

A Class, consisting of the following materials applied in the field by hand:

1. Coal tar pipeline primer (applied cold)
2. Coal tar pipeline enamel (application 350-375° F.).
3. Coal tar pipeline enamel (application 350-375° F.).
4. 15-lb. coal tar impregnated asbestos wrapper (applied by hand). Overall thickness 3/32-inch minimum—1/8-inch average.

B Class, consisting of the same materials as A with one added slick coat of pipeline enamel (application 350-375° F.) applied in the field by hand over the wrapper. This provided a smooth surface for bore installations under highways or railroads. Overall thickness—1/8-inch minimum—1/8-inch+ average.

C Class, consisting of the same materials applied in the field by hand:

1. Coal tar pipeline primer (applied cold).
2. Coal tar pipeline enamel (application 350-375° F.).
3. Coal tar pipeline enamel (application 350-375° F.).

4. 15-lb. coal tar impregnated asbestos wrapper.
 5. Coal tar pipeline enamel (application 350 - 375° F.).
 6. Coal tar pipeline enamel (application 350 - 375° F.).
 7. 15-lb. coal tar impregnated asbestos wrapper applied in the field by hand.
- Overall thickness— $3/16$ -inch minimum — $7/32$ -inch average.

Intermittently 39.4 miles of the 80 miles total were coated with these three modifications of the coal tar protective coatings along portions of the route which were traversing soil types 2, 3 and 4. The heavier double-wrap coating had been applied only in the most corrosive soil.

(2) *Asphalt Protective Coatings*

A Class, consisting of the following materials applied in the yard by machine:

1. Asphaltic inhibitive pipe primer (cold application).
2. Asphalt coat (application 325° F.).
3. Asphalt coat (application 325° F.).
4. 40-lb. rag felt soil proof pipe covering.
5. Asphalt coat (application 325° F.).
6. 40-lb. rag felt soil proof pipe covering muslin type.
7. Asphalt coat (application 325° F.).
8. Duplex Kraft paper.

Overall thickness $1/4$ -inch minimum — $9/32$ -inch average.

Approximately 14.7 miles of 80 miles total were coated with this type of asphalt base materials. At

the time of pipeline construction, this type of asphalt coating was evaluated on a part with the coal tar coatings. It had been applied through soil types 2, 3 and 4 encountered in the central section of the line.

B Class, consisting of the following materials applied in the field or yard:

1. Asphaltic inhibitive pipe primer (cold application).
2. Asphalt coat (application 325° F.).
3. Asphalt coat (application 325° F.).
4. Muslin wrapper.

Overall thickness — $1/8$ -inch minimum — $5/32$ -inch average.

(3) *Petroleum Grease Type Protective Coating*, consisting of the following applied in the field:

1. Petroleum grease (applied cold).
2. Wrapper.
3. Service coat (applied hot above 220° F.).

Overall thickness— $1/16$ -inch minimum — $3/32$ -inch average.

The latter two coatings were applied over approximately 12 miles of the line laid in 1929; 2.5 miles being coated with petroleum grease, wrapper and service coat, and approximately 9.5 miles with hot asphalt and muslin wrapper.

Selection of the coating for this portion of the line was made without the guidance of a soil survey because the line was laid prior to adoption of soil surveys as a standard practice in our Company. By 1932,

TABLE III

| NAME OF PIPE LINE | Size, Inches | Coating | Date Coating Inst. | Date Cathodic Protection Started | Miles of Main Protected | Number of Cathodic Stations | Station Rating Volts | Station Rating Amps. | Remarks |
|-------------------|------------------|-------------------|--------------------|----------------------------------|-------------------------|-----------------------------|----------------------|----------------------|-------------------------|
| San Diego... | 12 $\frac{3}{4}$ | Coal tar A..... | 9-32 | 7-33 | 5.6 | 1 | 6 | 5.0 | |
| San Diego... | 12 $\frac{3}{4}$ | Coal tar A..... | 9-32 | 12-32 | 10.7 | 1 | 5 | 10.0 | |
| San Diego... | 12 $\frac{3}{4}$ | Asphalt or Grease | 2-30 | 1-34 | 14.1 | 6 | 10 | 35.0 | |
| San Diego... | 12 $\frac{3}{4}$ | Coal tar A..... | 9-32 | 9-32 | 1.4 | 1* | | 0.07 | *1 cell gravity battery |
| San Diego... | 12 $\frac{3}{4}$ | Coal tar A..... | 9-32 | 7-35 | 1.7 | 1† | | 0.02 | †2 cell gravity battery |

when the rest of the line was built, it was found that the condition of the "B" Class of (3) petroleum grease type of coatings had deteriorated to some extent and it appeared that supplementary protective measures would be needed in order to protect the line from excessive corrosion.

(4) *Bare Pipe* was laid through soil areas of type 1 and amounted to approximately 11 miles total.

(5) *Galvanized Pipe*. A very unique method of corrosion control was applied to those sections of the line which were laid across the sloughs and estuaries of small streams. A double dip galvanizing bath was given to the extra strong, $\frac{1}{2}$ -inch wall crossing, thus providing them with protection not only from without but also from within. Total length of such crossings amounted to 2.8 miles, with the longest extending 4247 feet.

Evaluation of Pipe Protection Measures

Although the engineering staff of the Company had full confidence in the accuracy of the soil resistivity measurements and in the correlation of resistivity data with expected soil corrosivity, nevertheless, they had never lost sight of the fact that for any given resistivity figure, there

exists considerable variation in corrosivity among the individual soils. Hence, resistivity measurements could not always be taken to represent an absolute value, especially at border-line cases of adjacent soil types.

To safeguard against such deviations even prior to the time of actual construction of the line (early in 1932) the management became interested in the possibility of limited application of cathodic protection as supplementary means of corrosion control on pipelines coated with inadequate or imperfect coating.

Following, in general, practices of other utilities whose installations have been in operation since 1929, our company completed two cathodic protection stations in the fall of 1932 on the newly completed San Diego line.

Application of cathodic protection, of course, modified an accurate appraisal of the corrosion protective properties of the coating because of the compensating value which drainage current renders to the otherwise inadequately coated line.

Indirectly, however, the relative values of the dielectric properties of the applied coating became apparent when coating resistances were measured and calculated from the data of potential surveys conducted along

the line, in obtaining design data for the cathodic protection stations.

The superior dielectric quality of one coating versus another was later confirmed, when the extent of protection per unit capacity of the rectifiers were compared. Such a comparison had been provided in an article by H. J. Keeling⁴ in which he presents the operating data shown in Table III.

The variation in the resistances of the applied coatings were found to range between 2000 ohms per sq. ft. and 10,000 ohms per sq. ft. in extreme cases. Later the spread became even more pronounced, considering the fact that for cathodic protection of approximately 11 miles of the coal tar coated line, the current requirements have been met by the output of one rectifier supplying initially two amperes and only four amperes at the present time. For the same period, current requirements for protection of approximately a 14-mile section of the poorly coated line installed in 1929 have been supplied by six rectifiers, with initial output of 180 amperes, which currently has been increased to 200 amperes by installation of the seventh station.

Cathodic Protection

Elsewhere it was stated that cathodic protection had been applied to the two sections of the San Diego pipeline as early as the fall of 1932, at the time of completion of these sections. In anticipation of its extensive application, if proved successful, the entire San Diego pipeline was divided into 19 electrically separate sections by installation of insulated couplings for the purpose

of providing closer control of applied drainage to individual sections with their purely local requirements.

To date, the entire line is divided into 11 sections by bonding some of the couplings and combining some of the sections into one. However, the line is cut up, electrically speaking, into additional short sections by isolation of all galvanized slough crossings.

The magnitude of extension of cathodic protection application to this line in the past 15 years could be best illustrated by the summary of cathodic protection equipment presently used, capital investment and the mileage of line which we consider as adequately protected; and is as follows:

Total number of rectifier type stations, Southern Counties Gas Company—20 (3 additional stations are owned by the San Diego Gas & Electric Company and provide limited drainage to the San Diego pipeline through bonds).

Total capital investment Southern Counties Gas Company—\$13,872.40* (by the end of 1946).

Total mileage of main cathodically protected—70.7.

Maximum protection in miles per station—11.0 (Station 14.1, Sec. 2).

Minimum protection in miles per station—1.1 (Station No. 58.9, Sec. 8)

Total Capital Investment in
Station 14.1\$545.00*

Fixed Charges:

Interest, Depreciation,
taxes—22% of
\$545.00\$119.90

Maintenance & Op-
eration—\$1.24 per
mile/mo. x 12 x
11.0 163.68**

Total annual costs
per station ..\$283.58

Total annual cost per
protected mile per
year 25.78

By comparison, the total annual
cost per protected mile per year
drained by Station 58.9, Sec. 8, is
determined as follows:

Total Capital Investment
in Station 58.9.....\$543.90*

Fixed Charges:

Interest, Deprecia-
tion, Taxes—22%
of \$543.90\$118.66

Maintenance & Oper-
ation—\$19.04 per
mile/mo. x 12 x
1.1 251.33**

Total annual cost
per station ..\$369.99

Total annual cost
per protected mile
per year 336.35

Total Annual Cost Per
Protected Mile Per
Year Over the Entire
Line\$108.20

The wide range in the costs of
protecting one mile per year of 12¾-
inch O.D. line could be easily ex-
plained by the fact that cathodic
protection station 58.9 is draining
1.1 mile of line, which is mostly bare,
while station 14.1 is protecting 11.0
miles of line wrapped with a single
wrap of coal tar protective coating
designated as "A" above.

Methods Employed to Check Cath- odic Protection Operation and Maintenance Costs

Although the engineering staff of
our company never entertained seri-
ous doubts concerning the ultimate
success of the cathodic protection
application as a supplement to the
protective quality of the pipe coat-
ings, at the same time it did not
lose sight of the fact that like many
other processes, it would continue
to render protection as long as it is
properly maintained in required op-
erating order. In many cases cath-
odic protection installations at the
start produced desired reduction in
occurrence of leaks, but later failed
to maintain the level of attained
protection and the "leak record" re-
turned to, or even exceeded, the fig-
ure which originally necessitated the
application of cathodic protection to
the line.

The operating engineers reporting
such cases explained such occur-
rences by lack of necessary routine
for checking operations of individ-
ual stations.

In order to enforce continuance of
proper operation of equipment, close

* Majority of stations are carried on the books
at prewar price levels.

** Maintenance and operating costs are ac-
tual present day costs.

on the book
costs are

District: San Diego Pipe Line

| Section Number | Sta. No. | Station Output | | | Station Output | | | Station Output | | | Station Output | | | Station Output | | | PIPELINE POTENTIAL TESTS* | | | Additional Notes |
|-------------------|-------------|-------------------|---------------|---------------|-------------------|---------------|---------------|-------------------|---------------|---------------|-------------------|---------------|---------------|---------------------|-------|-----------------------|---------------------------|-----|-------|---------------------|
| | | Date | Volts D.C. | Amps. D.C. | Date | Volts D.C. | Amps. D.C. | Date | Volts D.C. | Amps. D.C. | Date | Volts D.C. | Amps. D.C. | Upstream Minimum | | Downstream Minimum | | | | |
| | | | | | | | | | | | | | | C.P. No. | Volts | C.P. No. | Volts | | | |
| San Juan | 1.6 | 10.9 | 12.8 | 8 | 10.8 | 12.7 | 15 | 10.6 | 12.2 | 10.9 | 12.2 | 11.0 | 11.7 | 5.0 | 21 | 10 | 45 | 20 | 34 | |
| Christiano | 2.1 | 4.3 | 3.5 | ... | 4.4 | 3.5 | ... | 4.5 | 3.5 | ... | 4.4 | 3.4 | ... | 4.2 | 3.1 | 1.5 | 1.9 | 30 | 30 | |
| SB 17.1 | 14.1 | 10.0 | 1.5 | ... | 10.0 | 3.5 | ... | 3.9 | 3.9 | ... | 3.8 | 3.5 | ... | 3.5 | 3.8 | 1.7 | 17.9 | 30 | 45 | |
| 3 | 23.7 | 8.3 | 30.0 | ... | 8.4 | 30.0 | ... | 8.3 | 28.5 | ... | 10.0 | 1.5 | ... | 10.0 | 1.5 | 28.5 | 29.9 | 45 | 45 | |
| 3 | 26.6 | 6.4 | 23.1 | ... | 6.0 | 27.2 | ... | 6.0 | 25.4 | ... | 5.9 | 24.0 | ... | 5.9 | 24.0 | 31.98 | 31.98 | 60 | 60 | |
| 3 | 28.5 | 5.9 | 34.8 | ... | 5.8 | 34.8 | ... | 5.8 | 33.7 | ... | 5.7 | 34.1 | ... | 5.7 | 34.1 | 31.98 | 31.98 | 60 | 60 | |
| 3 | 30.5 | 5.4 | 21.5 | ... | 5.4 | 22.8 | ... | 5.6 | 22.0 | ... | 5.7 | 21.2 | ... | 5.6 | 20.5 | 32.76 | 32.76 | 38 | 38 | |
| 3 | 33.7 | 10.9 | 28.4 | ... | 11.7 | 27.2 | ... | 8.3 | 28.9 | ... | 8.3 | 26.9 | ... | 8.1 | 26.5 | 33.76 | 33.76 | 51 | 51 | |
| 3 | 33.7 | 6.6 | 5.5 | ... | 6.6 | 5.5 | ... | 6.6 | 5.5 | ... | 6.5 | 5.8 | ... | 6.5 | 5.8 | 33.76 | 33.76 | 51 | 51 | |
| 4 | 45.2 | 24 | 15.7 | ... | 23 | 15.2 | ... | 9.6 | 16.0 | ... | 2.6 | 10.4 | ... | 11.6 | 23.4 | 28 | 34.31 | 40 | 34.36 | |
| 4-5 | 50.3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 44.8 | ... | 34.36 | 34.36 | 40 | 40 | |
| 6 | 55.8 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 48.4 | ... | 40.45 | 40.45 | 33 | 33 | |
| 6 | 56.4 | 3.0 | 5.3 | ... | 3.1 | 6.0 | ... | 3.2 | 6.2 | ... | 3.3 | 6.0 | ... | 48 | ... | 48.45 | 48.45 | 43 | 43 | |
| 7 | 58.9 | 5.0 | 16.8 | ... | 5.1 | 16.0 | ... | 5.2 | 17.8 | ... | 5.4 | 18.5 | ... | 60 | ... | 43.61 | 43.61 | 76 | 76 | |
| 8 | 62.7 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 80 | ... | 37 | 69 | 30 | 30 | |
| 9 | 63.7 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 80 | ... | 41 | 47 | 47 | 47 | |
| 10-11 | 65.3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 90 | ... | 71 | 91 | 93 | 93 | |
| 11 | 67.6 | ... | ... | ... | 2.9 | 40 | ... | 2.9 | 42.0 | ... | 3.0 | 45.0 | ... | 100 | ... | 87 | 110 | 114 | 114 | |
| 12 | 67.6 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 114 | ... | 10 | 115.7 | 25 | 119.9 | |
| 13-16 | 70.5 | ... | ... | ... | 3.3 | 7.6 | ... | 3.3 | 7.5 | ... | 3.3 | 7.1 | ... | 120 | ... | 40 | 127 | 40 | 30 | |
| 17 | 80.2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 144 | ... | 54 | 155.7 | 89 | 169.9 | |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 170 | ... | 37 | 173.9 | 85 | 10 | |

* Pipeline connected to (—) terminal of instrument, rusty iron or vcltmer ground pipe connected to (+) terminal (unless otherwise noted).

4. Periodic surveys by installation of corrosion control coupons in duplicate, one pair of which is connect-

TABLE V
CATHODIC PROTECTION RECORD—MONTHLY COST REPORT

| Month: November, 1946 | | | | | | | | | | | | | | | | |
|------------------------------------|------------------------|-------------|-------------|---------|----------|-------------------|------------|---------------|---------|-------|-------------|-------|--|-------------|------------|-------------------------|
| Section Number or Name of Pipeline | Reading and Inspection | LABOR HOURS | | | | Total Labor Hours | Labor Cost | Material Cost | MILEAGE | | POWER | | | Misc. Costs | Total Cost | Cost Per Protected Mile |
| | | Rectifier | Maintenance | | Contacts | | | | Miles | Cost | Used K.W.H. | Cost | | | | |
| | | | Grounds | Coupons | | | | | | | | | | | | |
| 1 | 4 | | | | 4 | 5.33 | | | 50 | 3.05 | | | | 8.38 | 1.90 | |
| 2 | 4 | | 12 | | 16 | 18.84 | | | 50 | 3.28 | | | | 22.12 | 2.01 | |
| 3 | 6 | | | | 6 | 8.00 | | | 90 | 5.40 | 20.64 | 33.78 | | 47.18 | 3.32 | |
| 4-5 | 3 | | 16 | 24 | 43 | 45.23 | 105.85 | | 142 | 9.94 | 10 | 1.80 | | 169.88 | 8.71 | |
| 6 | 2 | | | | 2 | 2.63 | | | 24 | 1.61 | | | | 4.24 | 6.16 | |
| 7 | 2 | | | | 2 | 2.63 | | | 13 | 1.91 | | | | 3.88 | 3.88 | |
| 8 | 2 | | | | 113 | 121.68 | 75.78 | | 312 | 22.54 | 59 | 1.99 | | 221.09 | 20.51 | |
| 9 | 2 1/2 | | | | 3 1/2 | 7.4 | | | 4 | .28 | | | | 1.02 | .54 | |
| 10 | 3 | | | | 3 | 3.99 | | | 27 | 1.89 | 380 | 8.17 | | 14.05 | 5.02 | |
| 11 | 3 1/2 | | | | 4 1/2 | 2.21 | | | 15 | 1.05 | | | | 3.26 | 3.62 | |
| 12-16 | 2 1/2 | | | | 17 1/2 | 2.21 | | | 43 | 2.12 | 34 | 1.22 | | 7.40 | 1.71 | |
| 17 | 1 1/2 | | | | 1 1/2 | 2.21 | | | 43 | 3.15 | | | | 5.36 | 2.44 | |
| San Juan Capistrano: I.D. WO. 430 | 1 | | | | 1 | 1.47 | | | 12 | .84 | | 2.92 | | 5.23 | 2.91 | |
| Total | | | | | | 221.39 | 185.63 | | | | | 52.59 | | 516.09 | | |

ed to the drained line, the other unconnected to serve as a pilot. The weighing and the records of these surveys are made by the engineer in the general office. However, actual installation and removal of the coupons are made by the Division personnel.

Considerable importance is attached by our management to the records of maintenance and operating costs for each station and for an entire Division in which cathodic protection is used. The compilation of required information is routinized to about the same extent as the checking of the operating data for each station.

The "Cathodic Protection Record—Monthly Operating Report," Table IV, and "Cathodic Protection—Monthly Cost Report," Table V, are regularly mailed to the general office for further study, compilation of annual data and filing.

Conclusions

In reviewing detailed descriptions of the various methods of soil corrosion mitigation, which were applied to the 12 3/4-inch O.D. welded steel line prior, during, and after its construction, it is only natural for the reader to ask the author for an opinion regarding their relative merits and service performances. It is also quite proper for the reader to ask whether the practices in pipeline protection are remaining as they were 15 years ago or are they also undergoing changes? And so, what are these currently employed practices?

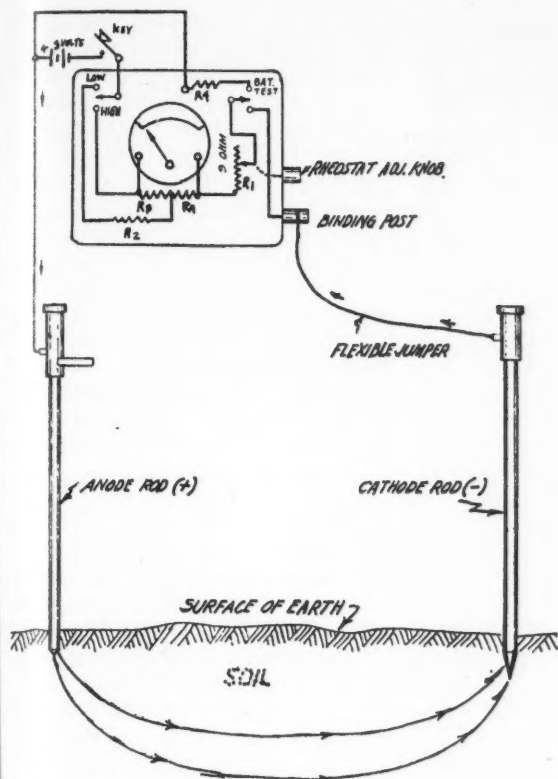


Figure 3—Diagram of Modified Earth Resistivity Instrument.

APPROXIMATE VALUES

- R₁ Battery adjustment—9 ohms.
- R₂ Low range series resistor—9 ohms.
- R₃ R₄ + R₅ instrument shunt resistor—1.5 to 2.0 ohms.
- R₄ High-low range ratio adjustment—0.5 to 0.7 ohms.
- R₅ Battery adjustment resistor—150 ohms.

In answering, we are going to discuss and evaluate them in chronological order:

Soil Survey—The best possible criterion of the value and the need for a soil survey is its ability to predict future corrosion activities of the soil along the newly constructed pipeline. Since soil resistivity is only one of the several characteristics of the alkali soil, which has an approximate relationship to its corrosivity, any survey which confines its study to the resistivity data only, is bound

to encounter inconsistencies. In our case the possible reason for the failure to identify more than the statistically probable number of "hot spots" could be attributed to the failure on our part to recognize: a) That the resistivity of the soil depends on the moisture content of the soil, which in arid climates varies during the year. In the summer and early fall, the moisture content of soil in California is low and makes soil resistivity readings too high. It was only in the latter phase of the

construction project that this omission was discovered, when coating specifications had already been in effect and complied with. b) That Shepard soil rods require very rigid care: periodic calibration of their sensitivity and careful selection of the dry cells (as far as voltage and amperage is concerned) are necessary. This was determined by investigations conducted by H. J. Keeling,⁵ and resulted in his modification of the original design. The changes are shown in Figure 3.

Our confidence in the value of soil resistivity data is retained till this day. Classifications of the soil types corrosionwise, however, had been reduced in number from the original 4 to 3; soils varying in resistance between 0 to 750 ohms cm are classed as very corrosive; between 750 to 10,000 ohms cm—corrosive (or at least unpredictable); above 10,000 ohms cm—non-corrosive.

Coatings—The satisfactory performance of pipe coatings composed of materials derived from coal tar, with adequate shielding from soil stresses by asbestos felt, was influential in standardization of our company's practices on coal tar coatings entirely.

Class C (above), commonly called double wrap, is used in soils with resistivity readings between 0-750 ohms cm and applicable to pipe sizes up to and including 4-inch I.D. Larger sizes call for special consideration.

Class A (above), commonly called single wrap is used in soils with resistivity readings between 750-10,000 ohms cm for all pipe sizes above and including 2-inch I.D. and 30-inch

O.D. All service pipe less than 2-inch I.D. is double wrapped with Class C coating regardless of soil type.

Bare pipe installations are no longer practiced by our company. In soil types having a resistivity range above 10,000 ohms cm, all pipe larger in diameter than 2-inch is installed with a uniform single coat of coal tar primer.

Galvanized slough crossings subject to corrosion by mud saturated intermittently with brackish or fresh water have rendered very satisfactory service. To date no leaks have been reported. However, the protective value of the zinc coating has been expended sacrificially in 15 years to such an extent that in places the brown color of an iron oxide is beginning to permeate the grey of galvanizing zinc. Presently, plans are under way to drain these crossings, either by means of conventional cathodic protection stations at locations where power is available, or by means of sacrificial anodes.

Cathodic Protection—Our belief in the effectiveness of the process has grown during the past 15 years in the same proportion as its expansion from the originally installed two stations in 1932. However, with the exception of Section 8, and several other short sections of pipe, we are still limiting its use to coated pipe lines. Application of the process to bare lines is still full of inconsistencies, some of which have been presented in H. J. Keeling's paper.⁶

The author has had a unique opportunity in going through the period of evolution in pipe protection practices to observe how one of the most modern and economically sound ideas of selecting protective

coatings to meet the local soil conditions has been once again replaced with an older previously discarded idea of uniform pipe wrapping extending the entire length of the line.

The explanation of a reversal lies in the requirements for greater pipe wall stresses in pipeline design; this in turn imposes a need for as consistently and uniformly an adequate protection of the thin-walled pipe as can be provided.

Among other contributing factors which influenced the change are: a) the most universal acceptance of cathodic protection as a means of extending and supplementing corrosion protection of buried and properly coated steel pipe at a very nominal cost; b) the successful development of traveling type of coating machines, which from the purely operational requirements, increased the cost of intermittent coating application to such an extent that a cost of uniform coating becomes justifiable; c) the excellent service record for the past 20 years of certain combinations of coating materials, as protective covering for steel pipe which

insures a much greater salvage value of the pipe after retirement; d) the growing dependence of natural gas utilization markets upon uninterrupted storage and transmission services of the long distance pipeline, due to gradual depletion of local natural gas fields.

The aforementioned statements are not intended in any sense to convey an impression of dissatisfaction with corrosion protection methods or materials which were applied or used 15 years ago on the San Diego pipeline or any other line built at that time.

In the light of the current demands and requirements of the pipeline industry, it is only natural to admit that some of the practices of corrosion protection of the past appear to be insufficiently reliable to provide trouble free operation. This opinion, of course, might not be shared by corrosion engineers operating in other sections of the country or the state. In order to avoid the controversy, the author wishes to state that it is his own, personal opinion, which is not in any sense mandatory or correct.

References

1. E. R. Shepard, Pipe Line Currents and Soil Resistivity as Indicators of Local Corrosive Soil Areas, Research Paper No. 298, reprint from Bureau of Standards J. of Res., **6**, 683-708 (1931) April.
2. I. A. Denison, Methods for Estimating Corrosiveness of Acid Soils in Contact with Iron and Steel Pipe, The Oil & Gas J., **31**, 83+ (1932) Sept. 29. Publication approved by the Director of the Bureau of Standards, U. S. Department of Commerce.
3. Scott Ewing, Soil Survey Methods Are Essential Part of Any Corrosion Survey—American Gas Association Distribution Conference, Oil & Gas J., **30**, 42-4 (1932) Apr. 21. Publication approved by the Director of the Bureau of Standards, U. S. Department of Commerce.
4. H. J. Keeling, Cathodic Protection by Southern Counties Gas Company, Proc. Pacific Coast Gas Assoc., **27**, 109-111 (1936).
5. H. J. Keeling, Some Theoretical and Practical Data on the Care and Use of Soil Resistivity Rods, Proc. Pacific Coast Gas Assoc., **32**, 135-151 (1941).
6. H. J. Keeling, A Cathodic Protection Installation on Bare Pipe, Proc. Pacific Coast Gas Assoc., **33**, 52-55 (1942).

Selected Bibliography on Salt Spray Testing 1935-1946*

By Lorraine R. Voigt*

Apparatus and Testing Material

Report of Sub-Committee VII on Accelerated Tests. *ASTM Proc.*, 26, Pt. I, Committee Reports; Tentative Standards, 144-151 (1926).

In the Bureau of Standards sodium chloride spray test the specimens are placed within an enclosed space and subjected to a fog of 20% solution. The specimens are removed every 24 hours, brushed with a stiff bristle brush and examined.

Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys. *ASTM Proc.*, 27, Pt. I, Committee Reports; Tentative Standards, 281-298 (1927).

With the present technique, the applicability of the spray test is limited and the method offers little promise as a general means for determining the corrosion-resistance of metals. A submitted plan prepared for a tentative standard spray test apparatus includes: 1) 24 by 20 in. glazed stoneware tank with baffle plate; 2) ¼-inch glass rods for specimen suspension; 3) ¼-inch glass tube inlet; 4) 2-inch glass tube exhaust; 5) spray nozzle as adopted by Sub-Committee on Spray Tests after making comparative performance tests of possible types; 6) air control; and 7) heating device.

Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys. *ASTM Proc.*, 32, Pt. I, Committee Reports; Tentative Standards, 201-225 (1932).

Results of an investigation showed that the salt spray test offers little promise as

a general means for determining the corrosion resistance of metals. The main difficulty is that the apparatus has not been standardized except for the box which in a measure has been adapted from that described in a paper by Rowdon, Krynitzy and Finkeldey presented in 1924. The nozzle should be of an inspirator type made of Monel, air pressure should be 20 to 50 lbs., air consumption should be 150 cu. ft. per l. of solution. The spray or mist should be introduced beneath the specimens, allowed to rise and vent itself around the top of the box. The specimens should be exposed as nearly vertical as possible. By inclusion of specimens of standard materials having known corrosion losses it is possible to eliminate errors from temperature changes or other operating variables.

Report of Sub-Committee IV on Methods of Corrosion Testing. *ASTM Proc.*, 33, Pt. I, Committee Reports; Tentative Standards, 178-208 (1933).

Construction of the salt spray cabinet and the dimensions of the test specimen used are shown. In the Navy standard salt spray tank 20% sodium chloride by wt. in distilled water is employed, sufficient solution being contained in the bottom of the cabinet for 72 hours operation. Air for atomization is humidified in an air washing column filled two-thirds full with distilled water, maintaining a pressure of 10-12 lbs. The test is run at 70-80° F. for 72 hours. The salt spray test does not compare favorably with the boiling nitric acid test in yielding reproducible data. The test may not be considered as quantitative nor are its results reproducible. No important decisions should be based on salt spray test data.

* Voluntary contribution. Sources of information: Inco Subject File, Chemical Abstracts and J. Inst. of Metals.

* The International Nickel Co., Inc., New York, N. Y.

Report of Committee B-3 Corrosion of Non-Ferrous Metals and Alloys. *ASTM Proc.*, 37, Pt. I, Committee Reports; Tentative Standards, 201-202 (1937).

Sub-Committee III reports the effects of temperature on salt spray test results and proposes the establishment of a standard salt spray test.

Tentative Method of Salt Spray Testing of Non-Ferrous Metals (ASTM B-117-39 T). *ASTM Standards*, Supplement, Pt. I, (1939).

Test is described completely. The apparatus required consists of a spray chamber, a salt solution reservoir, spray nozzle or atomizer, source of clean compressed air and, in some cases, temperature control devices. In operation the spray chamber must be uniformly filled with a dense fog and provisions for venting and draining the chamber must be provided. There must be a reservoir for fresh salt solution and spray nozzles must be of hard rubber, glass or Monel. Specimen holders must insulate the specimens and support them vertically or at some slope so that the corrosion products and condensate from one specimen do not fall on others. Details of specimens are given. 3.5 or 20% by weight sodium chloride solution in distilled water should be used of pH 6-7. The test may be operated at room temperature or $35 \pm 2^\circ \text{C}$. Standard exposure periods should be 16, 24, 48, 96, 200, 500 and 720 hrs.; 6, 8, 12, and 26 weeks and 1 year. Specimens should not be cleaned during test.

Report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys. *ASTM Proc.*, 39, 245-246 (1939).

Sub-Committee III recommends a proposed "Method of Salt Spray Testing of Non-Ferrous Metals" for publication as tentative, appearing in ASTM Standards, 1939, Pt. I. This Sub-Committee is undertaking a study of methods of calibrating salt spray fog densities and of salt spray testing in large chambers.

Tentative Method of Salt Spray Testing of Non-Ferrous Metals. (ASTM B-117-41 T). *ASTM Standards*, Supplement, Pt. I, 566-571 (1941).

The new revision states that the compressed air supplied to the nozzle shall have a relative humidity of at least 90% attained by passing the air through a saturator. For chambers operating at elevated temperatures the air shall be heated to and humidified at the operating temperature before being supplied to the nozzle.

Standardization in the Realm of Corrosion. *Chemische Fabrik*, 9, 178-181 (1936) Apr. 17.

Detailed reports are made on "tentative specifications," of units of measure and methods and equipment to be used in corrosion research by the Deutsche Gesellschaft für Chemisches Apparaturwesen.

Study of a Salt Spray Box of Large Dimensions. Paper before French Corrosion Committee, June 7, 1939 (Lab. Centrals Naval Artillery) *Metaux et Corrosion*, 14, No. 164, 66 (1939).

The apparatus is of wood and fibrocement, the usable space being 3m^3 . Two metal screens placed normal to the greatest axis of the box distribute the spray uniformly around the samples and insulate them from the disturbed zone by escape of compressed air. Two metal needle sprays are fed individually with fresh salt solution. Air pressure is $170 \pm 10 \text{ mm. Hg.}$ and 3 liters of solution are used every 24 hours.

***Metals Artificially Aged by Salt Spray.** *Machinery*, 46, No. 7, 128 (1940).

Westinghouse Lighting Division at Cleveland, Ohio, uses a salt-spray testing apparatus consisting of a pump supplying compressed air to a nozzle placed in a bath of salt water forming a cloud of salty vapor that is cooled in a tank that houses the materials under test. The nozzle is similar in action to a paint spray gun. The stream of escaping air passes over the restricted opening of a tube extending up from the salt water bath, pulling the water through the tube and vaporizing it as it leaves the opening. Specimens are supported vertically in the tank.

Corrosion of Metals—III. Sheet Metal Ind., 229, 933-940, 954 (1946).

Factors influencing corrosion testing are discussed and tests used including salt spray tests are described.

Specifying Rust Preventives. J. Albin, *Iron Age*, 155, No. 23, 52-59 (1945) June 7. Humidity and salt spray cabinets and a weatherometer are illustrated.

Accelerated Corrosion Tests for Coatings of the Iron Phosphate Type. E. M. Baker, A. J. Herzig and R. M. Parke, *Amer. Electrochem. Soc. Trans.*, 56, 279-290 (1929).

Twenty percent sodium chloride spray (Burr. Standards Circ. No. 80, 1922) was found suitable for evaluating coating quality. Much depends on air pressure, size of spray particles and rate of exhausting the container.

Corrosion Tests in Germany. G. Boldbach, *Aircraft Eng.*, **3**, 195-196 (1931).

Tentative standard methods laid down by the Aluminum Board of Reichsausschuss für Metallschutz are given.

The Principles of Corrosion Testing. C. W. Borgmann and R. B. Mears, *ASTM Symposium on Corrosion Testing Procedures*, 3-30 (1937).

Tests such as salt spray or immersion tests can be employed either as special property tests or as accelerated life tests depending on the attitude of the user and his interpretation of the results obtained.

View Points Concerning a Commonly Used Method of Testing Corrosion. S. Brenner, *Tek. Tid.*, **69**, (Section Kemie) 5-8 (1937).

A discussion of the various precautions that must be taken in accelerated corrosion tests, including spray tests.

Laboratory Corrosion Tests. R. M. Burns, *Ind. & Eng. Chem. An. Ed.*, **17**, 299-302 (1945).

The technique of immersion, atmospheric, salt spray and soil tests is described.

A Glass Salt-Spray Nozzle. G. W. Carrie, *Chemist-Analyst*, **19**, No. 2, 23 (1930).

Spray Nozzle. J. C. Case, *Chemist-Analyst*, **20**, No. 1, 20-21 (1931).

A special nozzle which is not likely to become clogged is described.

Corrosion Test on Metallurgical Products. R. Cazaud, *Aciers Speciaux*, **9**, 473 (1934).

In the spray test: the attacking agent acts as a fog of fine droplets projected against the specimen, the pulverization occurring in a closed chamber lined with Pb. Two baffles are obliquely placed for the purpose of cutting the jet of spray to obtain a stable and uniform atmosphere in the chamber where the specimens are suspended. The liquid collects at the bottom. The glass sprayer is fed with compressed air at 18-25 cm. water pressure. The filtered air (filtered through glass wool) is saturated with moisture by bubbling through a gas flask, which prevents the salt from depositing on the orifice of the sprayer. Temperature does not have an excessive effect if kept between 10 and 25° C.

Metal Corrosion Tests. R. Cazaud, *Aciers Speciaux*, **7**, 257-262 (1932).

Standardization work of the Research Commission for Corrosion of Aeronautical

Metal Products is reviewed. Various tests are described. Spraying occurs in a closed box with a nozzle at one end which sends the spray against an inclined baffle. The box is tilted to cause run-off of the unused solution. A standard saline solution of sodium chloride, sodium carbonate and boric acid having the same pH as sea water was adopted. Studies of stainless steels by alternate immersion, salt spray and continuous immersion gave analogous results.

Methods and Equipment Used for the Study of Corrosion in the Institute of Metallurgy. J. Czochralski, G. Welter and W. Maruszewska, *Wiadomości Inst. Metallurg. Metalog.*, **3**, 84-89 (1936).

A description of methods and apparatus used for the study of corrosion from spraying with a 3% sodium chloride spray.

The Salt Spray Test. V. M. Darsey, *ASTM Bull.*, No. 128, 31-34 (1944).

Salt-Spray Corrosion Test. G. T. Dunkley, *Mech. World*, **118**, 179-181, 192-195 (1945).

Applications of the salt spray test are considered.

Principles of Immersion and Humidity Testing of Metal Protective Paints. A. C. Elm, *ASTM Bull.*, No. 142, 927 (1946); *Corrosion*, **3**, 501-538 (1947).

Salt Spray Equipment Recommendations. H. Faigen, et al, *Nat. Paint Bull.*, **9**, No. 5, 8, 13 (1945).

Methods and Apparatus for Corrosion Testing of Metals. G. Gollnow, *Chem. Fabrik*, 326-328+ (1931).

A general review including rapid methods.

Procedure for Testing Materials. L. W. Haase, *Kleine Mitt, Mitglied. Ver. Wassur, Boden-u. Lufthyg.*, **16**, 35-46 (1940).

Practical Corrosion Tester for Chemical Engineers. M. H. Heeren, *Chem. & Metall. Eng.*, **49**, No. 2, 216-217 (1942).

An apparatus often used at Armor Research Foundation to produce uniform conditions in a great variety of applications is diagrammed.

Experimental Methods for the Study of Corrosion. J. C. Hudson, *J. Soc. Chem. Ind.*, **52**, 69-76T (1933).

A review of laboratory and field methods.

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Simple Apparatus for Making Corrosion Determinations. G. Kuerner, W. O. Lory, *Chemist Analyst* **26**, 93-94 (1937).

The apparatus consists of a filter flask, a condenser and a C filter tube which are suitably connected. By means of compressed air a percolating effect is produced and the liquid is continually sprayed against the sample.

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Modifications in the Standardized Apparatus for Corrosion Testing by Means of Saline Mist. J. Lucas, *Fifteenth Mtg., Congr. chim. ind. (Bruxelles, Sept., 1935)*, 1936, 1-5; *Mim. artillerie France*, **16**, 703-32 (1937).

A description of modifications that have been made in the design of the apparatus. Standardized by the (French) Committee on Study of Corrosion of Metallurgical Products Required for Aeronautics.

A New Modification of the Standard Apparatus for Corrosion Tests by Salt Spray. J. Lucas and R. Colombet, *Journées de la Lutte Contre la Corrosion* (Paris, Nov. 19-24, 1938), 153-155 (1939).

A type of metallic nozzle atomizer with a small opening is proposed which produces a very tenuous saline fog with a low consumption of saline solution.

Test Generation and Chambers. W. W. MacDonald, *Electronics*, **16**, No. 2, 82-86, 203-204, 207 (1943).

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Equipping a Corrosion Laboratory. F. K. McKean, *Trans. Corr. Inst. Min Met.*, **48**, 86-93 (1945).

Details are given of alternate-immersion machines, agitated corrosion apparatus, salt spray cabinets, a steam cabinet and stressing blocks.

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ically reviewed and an apparatus designed to give consistent and reproducible results is described.

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A modified salt spray test using a solution containing 1% glacial acetic acid in addition to 20% sodium chloride is more satisfactory than the standard 20% salt spray test.

Practical Salt Water Spray Tank. L. Pessel, *Chemist-Analyst*, **20**, No. 1, 15-16 (1931).

Standardization of Salt Spray Tests. J. Pomey, *Metaux et Corrosion*, **12** No. 139, 47-51 (1937).

Conditions for Examining Corrosion of Steels in Wet Way. A. Portevin and E. Herzog, *Compt. rend.*, **199**, 789-791 (1934).

The density and fineness of the salt spray have a great effect.

An Accelerated Atmospheric Corrosion Test. H. Pray and J. L. Gregg, *ASTM Proc.*, **41**, 758-765 (1941).

An apparatus with wetting, drying and cooling compartments is detailed.

Effect of the Testing Method on the Determination of Corrosion Resistance. H. S. Rawdon and E. C. Groesbeck, *Bureau of Standards Tech. Paper*, **367**, 409-426 (1928).

Spray tests are discussed among others.

Types of Apparatus Used in Testing the Corrodibility of Metals. H. S. Rawdon, A. I. Krynetsky and W. H. Finkeldey, *ASTM Proc.*, **24**, Pt. II, 717-734 (1924).

Details of apparatus and procedure for salt spray tests are given.

Influence of Temperature on the Corrosion of Various Metals by Salt-Spray. M. Sauvageot, R. Marchand, *Corrosion by Sea Water (Academie Mediterraneane)*, **1937**, 173-183, March 25-27.

Corrosion Testing Procedures. K. O. Schmidt, *Z. fur Metallkunde*, **22**, 328-336 (1930).

The D.V.L. immersion and salt spray apparatus are detailed.

Salt Spray Test. M. B. Shirley, *Am. Electroplaters' Soc., Monthly Rev.*, **27**, No. 7, 513-520 (1940).

An Accelerated Spray Test for the Determination of the Relative Atmospheric

Corrosion Tests in Germany. G. Boldbach, *Aircraft Eng.*, **3**, 195-196 (1931).

Tentative standard methods laid down by the Aluminum Board of Reichsausschuss fur Metallschutz are given.

The Principles of Corrosion Testing. C. W. Borgmann and R. B. Mears, *ASTM Symposium on Corrosion Testing Procedures*, 3-30 (1937).

Tests such as salt spray or immersion tests can be employed either as special property tests or as accelerated life tests depending on the attitude of the user and his interpretation of the results obtained.

View Points Concerning a Commonly Used Method of Testing Corrosion. S. Brenner, *Tek. Tid.*, **69**, (Section Kemi) 5-8 (1939).

A discussion of the various precautions that must be taken in accelerated corrosion tests, including spray tests.

Laboratory Corrosion Tests. R. M. Burns, *Ind. & Eng. Chem. An. Ed.*, **17**, 299-302 (1945).

The technique of immersion, atmospheric, salt spray and soil tests is described.

A Glass Salt-Spray Nozzle. G. W. Carrie, *Chemist-Analyst*, **19**, No. 2, 23 (1930).

Spray Nozzle. J. C. Case, *Chemist-Analyst*, **20**, No. 1, 20-21 (1931).

A special nozzle which is not likely to become clogged is described.

Corrosion Test on Metallurgical Products. R. Cazaud, *Aciers Speciaux*, **9**, 473 (1934).

In the spray test: the attacking agent acts as a fog of fine droplets projected against the specimen, the pulverization occurring in a closed chamber lined with Pb. Two baffles are obliquely placed for the purpose of cutting the jet of spray to obtain a stable and uniform atmosphere in the chamber where the specimens are suspended. The liquid collects at the bottom. The glass sprayer is fed with compressed air at 18-25 cm. water pressure. The filtered air (filtered through glass wool) is saturated with moisture by bubbling through a gas flask, which prevents the salt from depositing on the orifice of the sprayer. Temperature does not have an excessive effect if kept between 10 and 25° C.

Metal Corrosion Tests. R. Cazaud, *Aciers Speciaux*, **7**, 257-262 (1932).

Standardization work of the Research Commission for Corrosion of Aeronautical

Metal Products is reviewed. Various tests are described. Spraying occurs in a closed box with a nozzle at one end which sends the spray against an inclined baffle. The box is tilted to cause run-off of the unused solution. A standard saline solution of sodium chloride, sodium carbonate and boric acid having the same pH as sea water was adopted. Studies of stainless steels by alternate immersion, salt spray and continuous immersion gave analogous results.

Methods and Equipment Used for the Study of Corrosion in the Institute of Metallurgy. J. Czochralski, G. Welter and W. Maruszczka, *Wiadomosci Inst. Metallurg. Metalog*, **3**, 84-89 (1936).

A description of methods and apparatus used for the study of corrosion from spraying with a 3% sodium chloride spray.

The Salt Spray Test. V. M. Darsey, *ASTM Bull.*, No. 128, 31-34 (1944).

Salt-Spray Corrosion Test. G. T. Dunkley, *Mech. World*, **118**, 179-181, 192-195 (1945).

Applications of the salt spray test are considered.

Principles of Immersion and Humidity Testing of Metal Protective Paints. A. C. Elm, *ASTM Bull.*, No. 142, 927 (1946); *Corrosion*, **3**, 501-538 (1947).

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Practical Salt Water Spray Tank. L. Peschel, *Chemist-Analyst*, **20**, No. 1, 15-16 (1931).

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Conditions for Examining Corrosion of Steels in Wet Way. A. Porievin and E. Herzog, *Compt. rend.*, **199**, 789-791 (1934).

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Corrosion Testing Procedures. K. O. Schmidt, *Z. fur Metallkunde*, **22**, 328-336 (1930).

The D.V.L. immersion and salt spray apparatus are detailed.

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An Accelerated Spray Test for the Determination of the Relative Atmospheric

Corrodibility of Ferrous Materials. T. Swinden and W. W. Stevenson. *J. Iron & Steel Inst.* **140**, No. 11, 165-189P (1940).

Apparatus for Evaluating The Corrosion Resistance of Metals. G. O. Taylor, *Corr. Machinery*, **56**, No. 2, 76, 124 (1945).

The apparatus provides a constantly and automatically changing point of drainage on every specimen under test. This eliminates the disadvantages of standard tests (such as salt spray tests) in which it is difficult to provide a stable concentration of atomized mist over the entire interior of the apparatus.

Manual of Operation for Salt Spray Testing Equipment. H. P. Troendly, *Am. Electroplaters' Soc. Monthly Rev.*, **32**, No. 11, 1110-1114 (1945).

Instructions for Operating a Salt-Spray Cabinet. H. P. Troendly, *Natl. Paint Bull.*, **9**, No. 5, 58 (1945).

Apparatus for Examination of Processes of Metal Corrosion. N. A. Udalov, *Zavodskaya Lab.*, **5**, 195-198 (1936).

Construction and operation details of a "wet chamber" for corrosion tests are given.

Basic Requirements in the Standardization of the Salt Spray Corrosion Test. L. J. Waldron, *ASTM Proc.*, **44**, 654-662 (1944).

Salt Spray Testing Procedure. W. Wright, *Official Digest Fed. Paint Clubs Amer.*, **236**, 212-219 (1944).

Spray Test on Metals. Y. Yamamoto and T. Mori, *Bull. Inst. Phys. Chem. Res.*, (Tokio), **19**, 874-901 (1940).

Spray Test of Metal. Y. Yamamoto and T. Mori, *Bull. Inst. Phys. Chem. Res.* (Tokio), **19**, 901-922 (1940).

Applications

An Investigation of Aluminum Die-Casting Alloys—Nos. IVa and Va. *ASTM Proc.*, **36**, Pt. I, Committee Reports; Tentative Standard, 182-192 (1936).

Duplicate groups of five specimens of each alloy were exposed for three periods to salt spray at Aluminum Research Labs. and Bell Telephone Labs. The former used a standard spray tank the specimens being supported in slots in a wooden frame, while the latter employed a special tank and hung the specimens from glass rods with Al wire. 3½% sodium chloride spray at room temperature was used in each case. Corrosive conditions were most severe at the Aluminum Research Labs. Many variations were noted in the results and no incontrovertible conclusions could be drawn.

Tentative Specifications for Electrodeposited Coatings of Nickel and Chromium on Steel (ASTM A-116-39 T). *ASTM Standards*, Pt. I, 941-944 (1939).

The tests should be conducted with a 20% solution of sodium chloride (s.g. 1.15) under conditions producing a dense fog without the spray being blown directly against the specimens. The latter should be supported by glass or other insulating material and the temperature should be $95 \pm 5^\circ$ F. The condensed spray should be drained off and not used again.

Tentative Specifications for Electrodeposited Coatings of Nickel and Chromium on Steel (ASTM A-166-41 T) *ASTM Standards*, Supplement, Pt. I, 555-558 (1941).

Salt Spray test for continuity of coating: the specimen is cleaned immediately before testing so that the surface is free from "water break" and tested in accordance with the Tentative Method of Salt Spray Testing of Non-Ferrous Metals (ASTM B 117-41 T) using 20% sodium chloride solution (s.g. 1.15) under conditions producing a dense fog in the container without the spray being blown directly against the specimens. The temperature should be $95 \pm 5^\circ$ F. and the condensation of the spray should be drained off and not used again.

Accelerated Tests of Corrosion by Sea Water. *Aciers Speciaux*, **9**, 490-492 (1934).

A diagram compares the mechanical properties of Alumag after one month's testing by salt spray, sea water, alternate immersion, immersion in O₂ saturated water and laboratory immersion.

Protective Value of Electro-tin as an Undercoating. S. Wernick, *Electrodepositors' Tech. Soc.*, **20**, 47-60 (1944).

Specimens were tested in salt spray.

Testing the Atmospheric Resistance of Aluminum-Magnesium Alloys. *Metallwirtschaft*, 17, 593 (1938).

Six samples of each aluminum-magnesium alloy were sprayed 2 hours-5 minutes with artificial North Sea water (1440 gr. sodium chloride, 408 g. hydrated magnesium sulfate, 216 g. hydrated magnesium chloride, 98 g. hydrated calcium chloride in 50 l. water). It was concluded that salt spray tests give a hopelessly false picture of resistance of Al-Mg alloys to atmospheres.

Corrosion Resistance of Some Aluminum-Magnesium Alloys. *Metallwirtschaft*, 17, 343-353 (1938).

Simultaneous tests run in two laboratories on 3 aluminum-magnesium alloys are discussed. One used an artificial sea water spray of 27.3 g/l. sodium chloride, 3.3 g/l. magnesium chloride, 2.2 g/l. magnesium sulfate, 0.2 g/l. potassium bromide, and the other alternate immersion in 3% sodium chloride.

Aluminum-Beryllium Alloys. R. S. Archer and W. L. Fink, *AIMME Proc., of Inst. of Metals Div.*, 78, 616-643 (1928).

Sheet specimens of aluminum-beryllium alloys were subjected to 20% salt spray for 1300 hours at 14-20° C. The results showed the effect of Be in improving corrosion resistance of alloys not solution heat treated.

Corrosion of Ferrous Metals. R. Arzens, *Bull. Assoc. Tech. fonderie*, 5, 147-154 (1932).

Accelerated corrosion test was made by subjecting samples to sea water spray in a lead-lined box. Temperature was 15-25° and test duration 48 hours.

A New Advent in Aluminum Metallurgy. N. C. Ashton, *Metallurgia*, 1, No. 4, 148-150 (1930).

The most satisfactory means of causing accelerated corrosion was by using salt spray.

Corrosion-Protective Value of Electrodeposited Zinc and Cadmium Coatings on Steel RP 867. W. Blum, P. W. C. Strausser, A. Brenner, *Bureau of Standards J. of Research*, 16, 185-212 (1936), Feb.

The salt spray test was conducted with a 20% soln. of pure neutral sodium chloride in a room kept at 35° C. The nozzle, air pressure and baffle were so adjusted as to keep a uniform fine mist throughout the box and to wet uniformly the specimens, which were supported on glass at an angle of 45° from the horizontal. The solution that was condensed from the

spray was drained off and not used again. The salt spray test and intermittent immersion in sodium chloride may be used to measure roughly the minimum thickness of plated zinc coatings but not of cadmium coatings. Neither of these test measures the relative value of zinc and cadmium especially in an industrial atmosphere.

Standardization of Corrosion Tests for Light Metals. P. Brenner, *Chem. Fabr.*, 10, 486-491 (1937).

Test employing salt-spray, intermittent immersion, and immersion in moving liquids are discussed with respect to reproducibility of the results and their agreement with field tests.

Stress-Corrosion Studies on Light Metals. P. Brenner, *Zeitschrift fur Metallkunde*, 24, 145-151 (1932).

Elasticity and plasticity tests were made on two aluminum-magnesium-copper alloys before and after exposure in the D. V.L. salt spray apparatus to a 20% sodium chloride solution.

Rapid Corrosion Testing Under Mechanical Stress. P. Brenner and W. Toth, *Metallwirtschaft*, 16, 1295-1299 (1937).

An apparatus for elastic stressing and spray testing of specimens is described. The solution may be 3% sodium chloride and 1 vol. % conc'd. hydrochloric acid, 3% sodium chloride and 0.1% hydrogen peroxide or artificial sea water containing 2.9% sodium chloride, 0.77% magnesium chloride, 0.49% magnesium sulfate and 0.165% calcium sulfate.

Method for Testing the Resistance of Stainless Steels to Local Corrosion Attack. S. Brenner, *Iron & Steel Inst.*, Advance Copy No. 2, April, 1937, 11pp.

The method generally used is the salt spray test, consisting of: exposing the specimens for a long time to a fine spray of sodium chloride, sea water or the like. This method has, however, the defect, among others, that the intensity of corrosion is dependent upon the way in which the liquid deposits on the surface—whether drops are formed, or whether the whole surface is covered by a thin liquid film. Much time is required to carry out the test and, furthermore, it is difficult to maintain a constant temperature throughout the whole period—which in this case is very important.

Accelerated Test on White Interior Metal Finishes. J. B. Bullitt, Jr., *ASTM*

Symposium on Correlation Between Accelerated Laboratory Tests and Service Tests on Protective and Decorative Coatings, 9-10 (1937).

Satisfactory correlation was established between blistering tendencies in water-soak and humidity-cabinet tests at moderately elevated temperatures and the tendency of finishes to blister in service. Correlation with rusting was less satisfactory. The salt spray test in all of its modifications has been widely used for this purpose, but the author does not believe it to be of much value. Difficulty is experienced in obtaining duplicate results and they have not correlated well with actual service performance.

Electrolytic Finishes on Metal Improve Corrosion Resistance. H. L. Cableck, *Prod. Eng.*, 15, No. 11, 754-755 (1944).

Production testing of anodized coatings are described including salt spray tests.

Report on Accelerated Weathering Test of Paints. L. L. Carrick, *J. Assoc. Official Agr. Chem.*, 20, 350 (1937).

The cycle used in accelerated weathering tests on paints must be modified to suit climatic conditions.

Results of Accelerated Corrosion Tests on Stainless Steels. J. Cournot, *Compt. rend.*, 193, 1091-1093 (1931).

Alternate immersion, spray and immersion tests on stainless are discussed. The spray test showed up variations in mechanical properties, whereas the other tests were valuable for weight measurements.

Protection of Metals and Alloys Against Corrosion by Cadmium Plating. J. Cournot and J. Bary, *Compt. rend.*, 185, 773-774 (1927).

The resistance of the deposits was tested in salt mist.

Measuring the Effects of Corrosion by Decrease in Drawing Properties of KWI. J. Cournot and H. Fournier, *Revue de Metallurgie*, 31, 198-200 (1934).

Half of each lot of samples was submitted to the spray test for two months using artificial sea water.

The Corrosion of Refined Aluminum 99.992% Pure. J. Czochralski and J. Mikolajczyk, *Niadososci Inst. Metalurg. Metazoz*, 3, 108-110 (1936).

Refined aluminum (99.992%) and technical aluminum (99.63%) were compared as to their mechanical properties after

treatment with a spray of 3% sodium chloride solution.

Protective Value of Some Electrodeposited Coatings. L. Davies and L. Wright, *Metal Ind.* 36, 407-410 (1930), Apr. 11.

Salt spray tests of plated specimens are detailed.

The Effect of Cold Work on the Corrosibility of Cast Corrosion Resistant Steel in Salt Spray and Nitric Acid. J. A. Duma, *J. Am. Soc. Naval Engrs.*, 49, No. 4, 566-575 (1937).

A Comparison of the Performance of Anodic Coatings on Wrought Aluminum Alloys When Exposed to Salt Spray and to the Weather. J. D. Edwards, *ASTM Proc.*, 43, 182-183 (1943).

Determination of Loss of Strength and Ductility Due to Local and Intercrystalline Corrosion by Nondestructive Tests. W. Ehrenberg, *Korros. u. Metallschutz*, 17, 19-21 (1941).

Salt spray tests were among those used.

Corrosion of Steels by Weathering and Dilute Acids with Respect to Thermal Treatment and Cold Working. W. Eileneder, W. Geller and W. Ansel, *Korros. u. Metallschutz*, 17, 314-331 (1941).

Three steel samples of different origin and similar composition were subjected to corrosion tests in a sea-water spray apparatus, in the atmosphere and in running dilute acid. Loss of weight was determined.

Corrosion of Various Aluminum Alloys by Means of Salt Spray and Intermittent Immersion Testers. H. Endo and K. Miyazaki, *Kinzoku no Kenkyu*, 8, No. 4, 197-215 (1931).

Corrosion of Magnesium Alloys. 1st Report. Binary Magnesium Alloys. H. Endo and S. Morioka, *Science Repts.*, Tohoku Imp. Univ., 1st Ser., K. Honda.

Salt spray tests were among those used.

Institute of Metals—Pt. I, Corrosion at Discontinuities in Metallic Protective Coatings—Pt. II, Different Methods of Applying a Zinc Coating. U. R. Evans, *Metal Ind.*, 33, 229-232, 300-302 (1928).

Intermittent spraying with N/2 sodium chloride is considered.

Corrosion at Discontinuities in Metallic Protective Coatings. U. R. Evans, *J. Inst. Metals*, 40, No. 2, 99-140 (1928).

Intermittent spraying with normal 2 sodium chloride was used. Since in service metals usually fluctuate between wet and dry conditions it was believed that this test would give more valuable results than the spray test where the specimens are kept definitely wet all the time.

Finishing Warplanes—II. F. V. Faulhaber, *Metal Fin.*, **41**, No. 2, 113-114, 116-119 (1943).

Corrosion tests as specified in AN-QQ-A 69a should be conducted on anodized samples in accordance with AN-QQ-S-91 except that sheet samples should be inclined 6° from the vertical in the salt spray box. The exposure period should be 250 hours.

Corrosion of Aluminum Alloys Under Static Stress. G. Forrest, *Metal Ind.* **56**, No. 10, 229-230 (1940), Mar. 3.

The test pieces were loaded each at a given stress which was maintained constant until failure occurred, during which period they were sprayed with 3% sodium chloride three times a day.

Stress Corrosion in Relation to Aircraft Components. C. W. George and B. Chalmers, *ASTM-AIME Symposium on Stress-Corrosion Cracking*, Preprint No. 19, 1944, 9pp.

The stress-corrosion behavior of materials was investigated by observing time to failure of specimens maintained under a steady tensile load and sprayed with natural sea water 3 times a day.

Surface Protection of Elektron. Corrosion Protection of High Strength Magnesium Castings. H. Giehmann, *Korros. u. Metallschutz*, **14**, No. 1, 9-13 (1938).

Sheets of Elektron metal were exposed daily for 4 months to a water fog for 8 hours remaining dried in air the other 16 hours.

Some Comparative Corrosion-Fatigue Tests Employing Two Types of Stressing Actions. H. J. Gough and D. G. Sopwith, *J. Iron & Steel Inst.*, **127**, No. 1, 301-335 (1933).

Tests were made to investigate the comparative influences of cycles of reversed direct and reversed flexural stresses while the specimens are subjected simultaneously to salt spray.

Salt Spray Evaluation of Oiled Black Oxide Coatings on Steel. A. K. Graham, *Metal Fin.*, **40**, No. 5, 254-255 (1942).

Employing salt spray equipment designed and operated substantially as de-

scribed in Army-Navy Aeronautical Specification AN-QQ-S91 (950° F.) with 20% by wt. sodium chloride brine of 1.151 s.g. wt. (60° F.) results in less difficulty in obtaining reasonably good confirmation of findings of other laboratories.

Corrosion of Light Alloys. G. Guzzoni, *Alluminio*, **3**, 3-12 (1934).

The corrosion of three series of light alloys in 20% salt spray was determined.

Corrosion and Protection of Light Alloys. E. E. Halls, *Metal Treatment*, **2**, 11-111 (1936).

Nine major types of light alloys are discussed with respect to theory of corrosion resistance, salt spray and humidity tests and methods of protection.

Outdoor Atmospheric Corrosion of Zinc and Cadmium Electrodeposited Coatings on Iron and Steel. C. L. Hippensteel and C. W. Borgmann, *Trans Amer. Electrochem. Soc.*, **58**, 23-41 (1930).

Outdoor and intermittent water spray tests were conducted. Results agreed quite closely. However, after the spray was in operation, the zinc and zinc alloy coatings corroded at a considerably accelerated rate, while the corrosion of the Cd coatings was unaffected by the spray.

Corrosion Research on Light Metals—I. F. Horn, *Metal Ind.*, **42**, 173-176 (1936).

The salt spray and other tests are considered.

The Variation in Corrosion Properties Over Two Magnesium Alloy Sheets. E. R. W. Jones and M. K. Petch, *J. Inst. Metals*, **7**, Pt. III, 129-137, (1946), Nov.

Sea water spray corrosion tests with water from the English Channel were made at outdoor temperatures.

Corrosion Tests on Colored Cadmium Coatings. H. Krause, *Mitt. Forschungsinst. Proberamt Edelmet.*, **6**, 50-54 (1932).

Samples were exposed to salt-spray, atmospheric influence and dipping.

Comparison of Rust Protection of Iron by Zinc, by Cadmium and by Zinc-Copper Alloys and the Electrodeposition of Such Alloys. F. C. Mathers and R. L. Hardy, *Proc. Indiana Acad. Sci.*, **38**, 183-185 (1928).

The metals were sprayed with 5% salt solution to induce rapid rusting.

Corrosion of Metals Used in Aircraft—III. Methods of Exposure—RP 1316. W.

Mutchler, *Bur. of Standards, J. of Research*, **25**, 75-81 (1940).

The majority of the accelerated corrosion tests were conducted by either the intermittent-immersion or salt spray methods.

Protecting Ferrous Materials from Corrosion by Electro-Deposits of Zinc and Cadmium. F. Pietrafesa, *Met. ital.*, **26**, 937-948 (1934).

The resistance of cadmium and zinc plated iron to the corrosive action of a 20% salt spray was determined.

Atmospheric Exposure and Laboratory Tests on Nonferrous Screen Wire Cloth. G. W. Quick, *ASTM Proc.*, **30**, Pt. I, 864-880 (1930).

Results of salt spray tests are reported.

Laboratory Tests on Nonferrous Screen Wire Cloth. G. W. Quick, *ASTM Proc.*, **26**, Pt. I, 492-498 (1926).

Salt spray tests are discussed.

Corrosion Phenomena and Corrosion Tests on Light Metals for Aircraft. E. Rackwitz, *Korros. u. Metallschutz*, **3**, 171-177 (1929).

Test decided on simulated natural conditions as much as possible, i.e., sea water, fog or spray tests under ultraviolet light irradiation and comparison of natural outdoor weathering tests.

Testing the Corrosion Resistance of Alclad. E. Rackwitz and E. K. Schmidt, *Korros. u. Metallschutz*, **5**, 130-141 (1929).

Salt spray tests were among those used.

Test Methods for Evaluation of the Corrosion Resistance of Metals to Weathering and Sea Water. E. Rackwitz and E. K. Schmidt, *Korros. u. Metallschutz*, **5**, 7-13 (1929).

Spray tests were among those employed.

Sprayed Stainless Steel Resists Wear and Corrosion Under Trying Conditions. W. C. Reid, *Welding Engr.*, **21**, No. 6, 25-26 (1936).

Metallized stainless was tested with salt spray.

Investigation of Duralplate Sheets: Corrosion Tests. K. O. Schmidt, *Z. fur Metallkunde*, **24**, No. 3, 59-62 (1932).

The salt spray apparatus of D.V.L. was used.

Relations Between the Composition of Bath, Sediment, Coatings and Their Corrosion Resistance in Known Phosphating

Systems. L. Schuster and R. Krause, *Korros. u. Metallschutz*, **18**, 73-81 (1942).

Corrosion resistance at the coatings was determined in salt spray apparatus.

Rapid Tests for the Corrosion Resistance of Aluminum and Its Alloys. J. W. Smith, *Light Metals*, **1**, 124-125 (1938), May.

A common corrosion test for aluminum and its alloys is carried out in a salt solution or salt atmosphere.

Salt Spray Corrosion Tests on Electrically Deposited Zinc-Cadmium Alloys. L. E. Stout and C. L. Faust, *Metal Ind.*, **28**, No. 8, 381-383 (1930).

Accelerated Tests of Nickel and Chromium Plating on Steel. P. W. C. Strausser, A. Brenner and W. Blum, *Bureau of Standards J. of Research*, **13**, 519-26 (1934).

Use of the salt spray test is detailed.

Porosity Tests on Electro-Plated Coatings. P. W. C. Strausser, *Amer. Electroplaters' Soc. Proc.*, **1939**, 194-200.

The ferroxyl and salt spray tests are considered.

Practical Examination of the Corrosion Resistance of Light Alloys. G.-V. Taylor, *Metallurgia*, **25**, No. 147, 63-66; (1942), No. 148, 101-103 (1942).

Use of the "sea mist" test is considered.

Corrosion Tests on Mild Steel Wire by Spray Method. E. J. Virgin, *Statens Provingsanst.*, Stockholm, Medd., **58**, 12-15 (1933) (in Eng. 17-18).

Corrosion Resistance of Some Commercial Aluminum Alloys in Sea Water. J. F. J. Thomas and A. C. Halferdahl *Can. Chem. Process Ind.*, **28**, 257-259 (1944).

The conditions of exposure comprised salt spray tests and sea water immersion.

Testing of the Corrosion Resistance of Aluminum Alloys and Also of Elektron and Steel in a Fog of 3% Sodium Chloride Solution. G. Walter and Marus, W. Zeuska, *Wiadomosci Inst. Metalurg. Metaloz.*, **4**, 93-97 (1937).

Corrosion Tests on Zinc Sheets in Sodium Chloride Solutions. G. Wassermann, *Korros. u. Metallschutz*, **18**, 21-25 (1942).

Stirring, alternate immersion and spray tests were carried out.

Standardization of Corrosion Tests for Aluminum. A. Von Zeerleder, *Schw. Archiv. angew. Wiss. Tech.*, **6**, 33-40 (1940).

The salt spray test is discussed among others.

Advantages and Disadvantages

First Report of the Corrosion Committee. Iron and Steel Industries Research Council. Iron & Steel Inst., 1931, Advance Copy, 250 pp.

The intermittent salt spray test carried out under carefully controlled standardized conditions has been found to give comparable results in good agreement with those obtained in field tests. As an index to the extent of corrosion the weight increment is sufficiently accurate for industrial purposes if care is taken to keep corrosion from dropping off.

Salt Spray Test Defended by Government Metallurgist, Steel, 99, 51 (1936), Aug. 24.

The salt spray test is often criticized as a basis for predicting the behavior of stainless steels under general service conditions. Some of this criticism is probably justified, but, nevertheless, the test may be useful for showing whether or not the surface of the material has been finished in such a way as to insure the maximum corrosion resistance of which it is capable.

Plating of Rolled Zinc and Zinc Base Die Castings. E. A. Anderson and C. E. Reinhard, Res. Bull. New Jersey Zinc Co., Nov. 1929.

The 20% salt spray is useful for revealing defective practice in plating plants but one cannot accept the endurance of a plated coating in salt spray as an index of useful outdoor life. Examples are given.

Corrosion Resistance of Iron-Chromium Alloys in Various Media—I. The Salt Spray Test. W. B. Arness and J. N. Ostrofsky, Trans. Amer. Soc. for Steel Treating, 20, 429-463 (1932).

Attention is called to some of the peculiarities and to the non-infallibility of the salt spray test, and to the resultant complications when using this testing method as an index to the behavior of large numbers of Fe-Cr alloys after a month's exposure to the spray. Producers and many users of rustless iron employ salt spray as a collateral but not final test in studies of factors affecting resistance of their products to corrosion. The degree of attack does not lend itself to quantitative measurement and one of the weakest points of the test is the difficulty of interpreting the results in terms of probable service performance.

Is Corrosion Testing Ripe for Standard-

ization? O. Bauer, Zeitschrift, fur Metallkunde, 28, 25-29 (1938).

The much used accelerated test with salt spray has been carried out in various places at various times and these are likewise not much comparable to each other and therefore incapable of being standardized.

Relative Value of Accelerated Corrosion and Outdoor Exposure Tests. W. Blum, Amer. Electroplaters' Soc., Monthly Rev., 23, 8-16 (1936).

It is valuable to have accelerated tests which will at least give an indication of the behavior of coatings under conditions more nearly approaching actual service conditions. The four requirements of a satisfactory accelerated test (significant, rapid, reproducible, expensive) are discussed as applied to the salt spray test. This test finds its justification in the assumption that many parts are subjected to a marine atmosphere in service and that salt spray contains as an accelerating agent a material (sodium chloride) which is present in certain types of exposure. Many factors such as the concentration of the sodium chloride solution, its pH, rate of spraying, size of drops, amount of air that passes and temperature affect reproducibility of salt spray tests.

Corrosion Testing. R. M. Burns, Metal Prog., 37, 290 (1940).

History of the salt spray test is given. By 1940 it was recognized that accelerated dependable tests cannot be relied upon to furnish dependable information of the corrosion resistance of specific metals under specific conditions of use. Consequently tests of this type have been abandoned except for the salt-spray test which is now used largely as a means of comparing the quality of different samples of the same or similar materials.

Conservations of Tin in Soft Solders. D. L. Colwell and W. C. Lang, Elec. Mfg., 32, No. 4, 226 (1943).

Salt spray test cannot be recommended as a quality check on electro-negative coatings; thoroughly standardized and properly conducted it can be useful in evaluating the degree of porosity of electro-positive coatings.

Salt-Spray Testing. E. H. Dix, Jr., and J. J. Bowman, ASTM Symposium on Corrosion Testing Procedures, 1937, 5767.

Much of the salt spray test's unpopularity probably results from uncontrolled variables and the lack of standardized procedures. Data are presented to show that the test is useful and reliable when properly administered. Factors to be controlled and standard conditions are discussed.

Examination and Determination of Quality of Electroplates. B. Egeberg, *Osterr. Chem.-Ztg.*, 43, No. 13-14, 134-137 (1940).

As an accelerated test, the salt spray is unreliable; it may give an indication of the porosity, however.

Preliminary Investigation of Laboratory Corrosion Tests. U. R. Evans and S. C. Britton, *1st Report of Corrosion Committee to Iron and Steel Ind. Res. Council*, 1931, 139-155.

Laboratory spray tests are of value in indicating the relative "liability to commence rusting" of different metals under typical service conditions. With a single spray vessel for all the metals tested good agreement is obtained in the weight gained by duplicate specimens. Spraying with sea water or 3.5% sodium chloride is recommended as a criterion of corrosion resistance in marine atmospheres.

Corrosion Testing of Electrodeposited Coatings. N. J. Gebert, *Metal Cleaning & Fin.* 2, 33-36 (1930).

The salt-spray method for determining pinholes in Ni, Cu, and Cr deposits has many disadvantages for routine production testing such as uncertainty of the end-point and the length of time required.

Corrosion Testing of Electrodeposited Metal. N. J. Gebert, *Amer. Electroplaters' Soc., Monthly Rev.*, 27, 755-760 (1940).

The salt spray is useful for testing zinc coatings because the salt solution dissolves the zinc at a measurable rate and primarily measures thickness of plate. However, for other coatings there are many disadvantages to the use of salt spray for routine production testing such as uncertainty of the end point and length of time required to test a good plate.

Accelerated Laboratory Corrosion Test Methods for Zinc-Coated Steel—RP 10. E. C. Groesbeck and W. A. Tucker, *Bureau of Standards, J. of Res.*, 1, 255 (1928).

The essential value of the salt spray test seems to lie in the use of a corroding solution which when atomized within the chamber containing the specimens, would be expected to remove the zinc coating

in a progressive and more or less even manner within a reasonable period of time. Details of spray testing are given. The spray test, at least with normal solutions of sodium chloride and ammonium chloride as the corrodent, has failed to show any merits which would recommend it as an accelerated test method for evaluating the service life of hot-dip zinc coatings.

Corrosion Tests in the Laboratory and Under Natural Conditions. G. Guidi, *Ind. meccan.*, 20, 112-115 (1938).

In general, tests under natural conditions are preferable to accelerated tests.

Investigation to Determine the Value of the Proposed Laboratory Tests. W. H. Hatfield and H. T. Shirley, *1st. Report of the Corrosion Committee to the Iron and Steel Ind. Res. Council*, 1931, 156-210.

Order of merit given by the field test for more heavily rusted materials does not compare well with that given by spray tests.

Fourth Report of the Corrosion Committee. W. H. Hatfield et al, *Iron & Steel Inst.*, 1936, 240pp. Section E.

While some progress has been made with the intermittent test, it fails to give an order of merit corresponding to that observed under atmospheric corrosion for materials whose corrosion resistances are not radically different.

Copper Steels. E. Herzog, *Aciers Speciaux*, 9, 364-377 (1934).

Salt spray tests continued without drying do not give results comparable to those obtained in marine atmosphere.

Spray Tests. C. E. Henssner, *Iron Age*, 149, No. 26, 65-66 (1942), June 25.

In salt spray testing the comparative condition of all panels at the end of a suitable test period is a better measure of value than is a comparison of time of initial failure. As regards time of initial failure, correlation between salt spray and outdoor exposure is negative. Between salt spray and ocean spray, 20% salt spray is preferable, as its results are less affected by temperature variation.

Advantages and Objections to the Salt Spray Test from an Electroplating Point of View. A. Hirsch, *Metal Fin.*, 39, No. 7, 356 (1941), July.

One of the advantages is that a comparison can be made of thin and thick deposits either on the same or separate pieces of work. Disadvantages are: there

is no complete correlation between salt spray tests and outdoor exposure, particularly for zinc and cadmium, and the test is particularly sensitive to physical conditions. The porosity of Ni coatings depends on such factors as polishing of the base metal and the presence of solid matter. Thickness measurements alone would not give a proper measure of the degree of corrosion resistance of Ni coatings and the salt spray test is thus valuable for evaluating porosity. One of the difficulties in obtaining uniform results in salt spray testing is improper wetting of the surface by the spray.

Is the Salt Fog a Test for a "Poor" Nickel Plate? G. B. Hogaboom, *Metal Fin.*, 43, No. 9, 372-373 (1945).

The real value of the nickel deposit as a protective coating can be determined only by testing the nickel deposit itself, rather than by the usual testing of nickel-plated steel.

Fifth Report of the Corrosion Committee. J. C. Hudson, *Iron & Steel Inst.*, 1938, 448pp. Section D.

There was no correlation between loss in thickness weight loss and decrease in breaking load of specimens tests with salt spray and those tested outdoors.

Laboratory Corrosion Tests. J. C. Hudson, *1st Report of the Corrosion Committee to the Iron and Steel Ind. Res. Council*, 1931, 211-219.

For copper free mild steels correlation between intermittent spray tests and field test results was good, provided the different sprays delivered approximately the same quantity of liquid per puff.

Finishing Methods Prior to Plating. G. A. Lux and M. Berdick, *Proc. Am. Electroplaters' Soc.*, 29, 19-26 (1942).

Specimens were tested with salt spray. Results were very erratic and showed no correlation with exposure test results. Their behavior suggested that the salt spray was slowly attacking the coatings producing pores where none existed before. These results cast doubt upon the value of the salt spray test for detecting pores in nickel coatings.

Experiments on the Corrosion of Light Metals by Attacking Waters. W. Mialki, *Aluminum*, 20, 315-320 (1938).

Tests with salt spray do not permit judging the resistance of light-metal sheets to water containing carbon dioxide and chlorine.

X-Ray Analysis of Corrosion Products from Galvanized Sheets (discussion). F. R. Morral, *Trans. Electrochem. Soc.*, 77, 279-288. (1940).

In salt spray tanks galvanized articles corrode fairly rapidly. Apparently a soluble or non-adherent product is formed, whereas at the sea coast galvanized products will stand up for extended periods of time. It has been suggested that an oxy-chloride is formed at the sea coast; you have the sun and its action to consider. The sun dries out the specimens and causes less soluble anhydrous compounds to form. In the salt spray test the pure zinc compound does not have a chance to dehydrate. That is why we do not have much faith in the salt spray test.

Testing Protective Coatings. E. A. Oillard, *Metal Ind.*, 31, 385-387 (1927).

An intermittent salt spray does give some of the effects of rain, but the conditions are never similar to those of the atmosphere and there is seldom any appreciable temperature change. Since, probably, a great deal of corrosion does not take place actually while the spray is in operation, there is no point in prolonging this period after its object, the removal or partial removal of the corrosion products, has been achieved. It is suggested that specimens be arranged in rows at an angle of 30° so that one row just overlaps the one beneath it. The performance of the specimens should be expressed in hours it withstands the test, first appearance of rust and breakdown of protective coating.

Behavior of Steels with Good Corrosion Resistance. A. Petinaud, *Journées de la Lutte contre la corrosion* (Paris, Nov. 19-24, 1938), 447-452 (1939).

Salt spray tests do not give an indication of what behavior in sea water would be.

Influence of Various Factors on Corrosion Tests. A. Portevin, *Metaux et Corrosion*, 15, 17-29 (1939).

Salt spray tests often give widely scattered results—fineness of spray, concentration of the solution, whether artificial saline or sea water being factors.

Comparative Corrosion Tests with Ordinary Cast Iron and Low Alloy Steel in Sea Water and in the Laboratory. A. Portevin and E. Herzog, *Korros. u. Metallschutz*, 14, No. 6/7, 204-213 (1938).

The salt spray test does not give the same distribution of attack as that obtained with longer outdoor exposures.

Comparative Tests in Service and in Laboratory for Sea Corrosion of Certain Low-Carbon Low-Alloy Steels. A. Portevin and E. Herzog, *Metaux et Corrosion*, 12, 201-209 (1937).

The laboratory salt spray tests do not agree with sea atmosphere tests.

Atmospheric Exposure Tests on Non-Ferrous Screen Wire Cloth—RP 803. G. W. Quick, *Bureau of Standards, J. of Res.*, 14, 775-793 (1935).

Tables show that the salt spray test cannot be used as a basis on which to predict the behavior of materials at exposure stations.

Report of Subcommittee III on Conformance Tests; Report of Replies to Questionnaire on Salt Spray Testing. C. H. Sample et al, *ASTM Proc.*, 43, 187-190 (1943).

The salt spray test is not, in the present form and application, adequate for use as the only accelerated test for comparing the quality of protective coatings.

Use and Misuse of the Salt Spray Test as Applied to Electrodeposited Metallic Finishes. C. H. Sample, *ASTM Bull.*, 1943, No. 123, 19-24.

The test is frequently useful in evaluating the degree of porosity of metallic coatings of the electropositive type, but cannot be recommended as a quality test for electronegative coatings.

Laboratory Corrosion Tests (of Iron and Steel). I. Automatic Apparatus for Laboratory Corrosion Tests by the Inter-

mittent Spray Method and Results Obtained Therewith. W. A. W. Schroder, *Iron & Steel Inst.*, 2nd Report. Corrosion Comm., 1934, 185-197.

Salt (NaCl) sprays do not give reproducible results, but the acid spray and a spray of 1.6% aqueous ammonium sulfate containing 0.4% ammonium chloride give very concordant results in duplicate tests.

II. Investigations to Determine the Value of the Proposed Laboratory Tests. W. H. Hatfield and H. T. Shirley, *Ibid.*, 197-209.

Accelerated spray tests are useful only for comparing the behavior of the more resistant materials for ordinary steels. The results obtained do not correspond well with those given by prolonged weathering under atmospheric conditions.

IV. Corrosion Tests on Ingot Iron and Various Steels in Sheet and Strip Form. H. Sutton, *Ibid.*, 221-225.

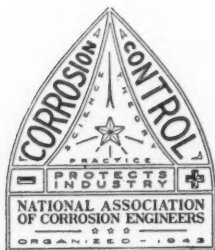
Weight loss data are given after weathering and intermittent salt spray tests.

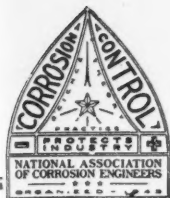
VIII. Corrosion Tests on Wires by the Decrease in Breaking-Load Method. J. C. Hudson, *Ibid.*, 253-266.

3.5% sodium chloride spray produces about twice as much corrosion as the field tests, but fails to show the beneficial effect of Cu in mild steel.

Corrosion Research. J. F. J. Thomas, *Canadian Chem. & Proc. Inds.*, 26, No. 3, 169-171 (1942).

With the salt spray test one can only interpret laboratory results into service life with extreme caution.





Topic of the Month

ALUMINUM PIPE TEST

By R. L. Bullock*

During April, 1948, the Interstate Oil Pipe Line Company placed in service one-half mile of 4-inch and one-half mile of 6-inch aluminum pipe in the sour crude fields near Magnolia, Arkansas. The pipe laid in Arkansas is being tested for resistance to internal corrosion of crude oils containing distillates, hydrogen sulfide gas and suspended particles of iron sulfide. Although the Arkansas sections were chosen primarily for internal corrosion, the actual sites were selected so as to contain varying types of soil. An additional one-half mile of 4-inch aluminum pipe was laid in the corrosive soils along the bank of the Inter-

Coastal Canal near Raceland, Louisiana. The Louisiana section is used only in sweet crude service, but the soil has been found to be highly corrosive to steel pipe.

The aluminum pipe, manufactured by the Aluminum Company of America, was made by extrusion in 40-foot lengths. A full joint of 4-inch pipe weighs 149 pounds and 6-inch pipe weighs 262 pounds. The aluminum alloy is 63S-T6, containing 98.9 percent aluminum, 0.7 percent magnesium, 0.4 percent silicon. This alloy has a tensile strength of 32,000 psi and a yield point of 25,000 psi. Each section of line was tested on the completion of the welding to 1000 psi hydraulic pressure. There was no failure of either pipe or weld

* Interstate Oil Pipe Line Co., Tulsa, Okla.



Aluminum flange being welded to aluminum pipe. Each section of aluminum pipe was insulated from adjoining steel pipe by means of insulated flanges.



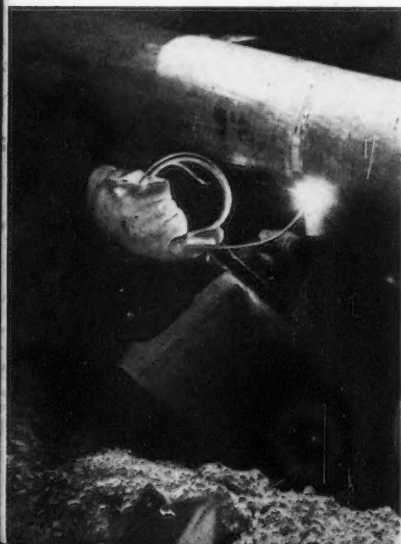
Completed weld, and attached aluminum wire lead.

and no pin-holes were found. In addition, two joints of 4-inch pipe were welded together for a special hydraulic test, and failure occurred in the weld at 2675 psi water pressure.

Welding of the pipe was done by the inert gas shielded tungsten arc welding process. Power was supplied by a gasoline driven engine, alternating current welding generator, which supplied 60 cycle current for welding (about 225 amperes at 80 volts) and a high frequency current (2 to 3 megacycles) to stabilize the arc. Argon gas is fed to the arc, so that the weld is blanketed with the inert gas, and the tungsten electrode is not consumed. Because of the high temperatures involved, the welding head is water cooled from the engine cooling system. The resulting weld is very clean and smooth, as no flux is involved.

Test sections have been flanged into the Arkansas sections of line so that they may be removed for visual

inspection of the interior surface. Insulated aluminum wire leads were welded to the pipe at frequent intervals and the terminals spotted at the surface of the ground, so that electrical measurements can be made. Each section of aluminum pipe is electrically insulated from the adjoining steel pipe by means of insulating flanges. This was done by welding a forged aluminum weld neck flange to the aluminum pipe and bolting it to a similar steel flange welded to the steel pipe. The sections of aluminum pipe laid were placed in the most corrosive sections of line and soils available. To abate the situation, part of the pipe was coated and wrapped, part was coated only, and some left bare. The entire job was planned with the able assistance of the Aluminum Company of America, to involve the worst conditions, and it is believed that if there is any weakness in the use of aluminum pipe, it will be discovered



Overhead welding on aluminum pipe. A plywood shield is used to keep wind from blowing protective cloud of inert gas away from weld and arc.



Typical welding scene on 6-inch aluminum pipe.



NACE News

GENERAL INTEREST

The sixth annual Pittsburgh Conference on X-ray and Electron Diffraction will be held November 19-20 at Carnegie Institute of Technology, Pittsburgh, Pa. The conference this year is being sponsored by Philadelphia members of the American Society for X-ray and Electron Diffraction, Carnegie Institute of Technology, University of Pittsburgh, and the Mellon Institute of Industrial Research. Technical papers will be presented in four sessions Friday and Saturday, mornings and afternoons. A dinner will be held Friday evening, following which Lawrence Bragg, Director of the Cavendish Laboratory, Cambridge, England, will deliver the principal address of the conference. Advance registration is requested, and should be forwarded to Mr. C. W. Cline, Aluminum Research Laboratories, Box 772, New Kensington, Pa. It is also requested that out-of-town visitors make their own hotel reservations. General Chairman of the conference is Roman Smoluchowski, Metals Research Laboratory, Carnegie Institute of Technology. Program Committee Chairman is Harold P. Klug, Mellon Institute.

The American Electroplaters' So-

ciety announced the selection of sites for its annual conventions for the next three years. Milwaukee, Wis., will be the location for the 1949 meeting, dates for which will be June 27 through 30. Convention Headquarters will be in the Schroeder Hotel. The 1950 Convention will be held in the Hotel Statler, Boston, Mass., and dates in June will run concurrently with the Fourth International Electrodeposition Conference. The 1951 Convention will be held on the West Coast, with Los Angeles the site.

Vaporizing metal samples in a small filament-type furnace has enabled Westinghouse Physicist William M. Hicham to trace metal impurities by means of a mass-spectrom-

Houston Section, which held a successful meeting September 13 with Robert Dillon, Carbide and Carbon Corp., Texas City, the principal speaker, has scheduled a meeting for October 18. The scene will again be the Houston Engineers' Club, and the time 6:30 P.M. A member of the Foundation of Applied Research and South West Research Institute of San Antonio will be the speaker. The section will also meet November 15 at the Houston Engineers' Club, when Monroe Shiely, Dow Chemical Co., is slated to present a paper on general corrosion.

eter. Using one milligram samples, the new method will detect as little as one part of the impurity per million. The equipment was devised for a special research project and is not available commercially. Mass-spectrometer has been used for some time in analysis of gases, but this is thought to be its first successful application to metals. Its use will permit completing an analytical job that had taken days by chemical means in a few minutes. The mass-spectrometer consists essentially of an ionization chamber and a curved section with narrow slots at each end. Ions of the vapor being analyzed are separated electro-magnetically, so that only those having certain atomic weights pass around

the curve and through the exit slot. These are deposited on a plate just beyond the slot. Their quantity is determined by measuring the charge on the plate.

Mutual Boiler Insurance Company of Boston has opened a sales and inspection office at 716 Mortgage Guarantee Building, 141 Carnegie Way N.W., Atlanta, Georgia. The sales office is under the direction of E. L. Gates, Jr. Inspections are under the direction of W. C. Lange. The company also announced the opening of an inspection office at 17 Exchange Street, Phenix Bank Building, Providence, Rhode Island. Inspections are under the direction of Jack Groves.

NEW CORPORATE AND ASSOCIATE MEMBERS

Following is a list of new Corporate and Associate members who have joined NACE during the period from August 16 to September 16, 1948, bringing to 228 the number of these types of sustaining Association memberships:

| | Representative |
|--|-------------------|
| Anglo-Iranian Oil Co., Ltd., New York, N. Y. | B. R. Jackson |
| Atlantic Refining Co., Producing Dept., Dallas, Texas | B. E. Moir |
| Atlantic Refining Co., Refining Dept., Philadelphia, Pa. | J. K. Deichler |
| Bastian Morley Co., Inc., La Porte, Ind. | H. B. Carbon |
| Bechtel Corporation, San Francisco, Calif. | J. S. Connell |
| Bull Dog Electric Products Co., Detroit, Mich. | James Unger |
| Byers, A. M., Co., Pittsburgh, Pa. | J. W. Harriman |
| Commonwealth Edison Co., Chicago, Ill. | A. D. Bailey |
| Fish Engineering Corp., The, Houston, Texas | Paul Hall |
| Flintkote Co., The, New York, N. Y. | N. W. Neher |
| Fruehauf Trailer Co., Detroit, Mich. | F. M. Reid |
| Graver Tank & Mfg. Co., Inc., East Chicago, Ill. | W. M. Broxham |
| Missouri-Kansas-Texas Lines, St. Louis, Mo. | K. H. Hanger |
| Petroleum Engineering, Inc., Houston, Texas | P. M. Raigorodsky |
| Pittsburgh Coke & Chemical Co., Pittsburgh, Pa. | Russell H. Coe |
| Potash Company of America, Carlsbad, N. M. | E. W. Douglass |
| Sline Co., Inc., Houston, Texas | Louis L. Sline |
| St. Louis-San Francisco Railway Co., St. Louis, Mo. | H. B. Barry |
| Union Pacific Railroad Co., Los Angeles, Calif. | Wm. Reinhardt |
| United Chromium, Inc., New York, N. Y. | R. O. Loengard |
| United States Pipe & Foundry Co., Burlington, N. J. | A. E. Schuh |
| Universal Oil Products Co., Burlington, N. J. | Eugene M. Matson |

PERSONALS

Willard H. Dow, president of the Dow Chemical Co., Midland, Mich., has been elected to receive the American Society for Metals 1948 Medal for the Advancement of Research. Presentation of the medal, plaque and citation will be made during the annual banquet of ASM to be held in Philadelphia October 28 during the National Metal Congress Exposition.

Ray R. West has been named manager of sales of the Minneapolis-Honeywell Regulator products for industrial applications. He will make his headquarters in Philadelphia, Pa.

J. C. McKenna, for the past six months product manager of chromium chemical sales for Diamond Alkali Co., Cleveland, Ohio, has been promoted to product manager of alkali sales. He succeeds J. D. Mattern, who retired in mid-August after 25 years' service with the company.

E. W. Chapman joined Tuthill Pump Co., Chicago, Ill., Sept. 1 as vice president in charge of engineering. He previously held a similar position with Bowser, Inc., Industrial Pump Div.

Gregory J. Comstock has been retained by Lake Erie Engineering Corp., Buffalo, as consultant of all matters relating to the field of powder metallurgy and application of equipment thereto.

Lawrence K. Richey, operations manager, and **Theodore W. Weigele**, gas engineer, have been elected vice-presidents of the Michigan Consolidated Gas Company, Detroit. They

will become responsible for the operations and gas engineering in all the Company's districts in Michigan. Mr. Richey joined Consolidated in 1920 as a cadet engineer. He had previously taught in country and city schools of Ohio following graduation from Ohio State University in 1916, where he majored in science and mathematics. Mr. Weigele, who is president of the Michigan Gas Association, started his professional career with Public Service Co. of New Jersey, after earning a degree in mechanical engineering from Stevens Institute of Technology in 1913. In 1914 he joined American Light & Traction Co., and two years later was transferred to Binghamton Gas Co., New York. After World War I, he was transferred to Detroit to take charge of the Gas Company's Station A, and has climbed steadily through the ranks to his present position.

Donald H. McLaughlin has been elected a director of The International Nickel Co., of Canada, Ltd. He fills the vacancy caused by the death of W. N. Cornwell. Mr. McLaughlin, who is president of the Homestake Mining Co., also serves as a director of Cerro de Pasco Copper Corp., Empire Trust Co., of New York, The Door Co., San Luis Mining Co., and the American Trust Co. of San Francisco. He also is a consulting engineer for the Cerro de Pasco Corporation, and chairman of the National Minerals Advisory Council, and chairman of the Advisory Committee on Exploration and Mining of the Atomic Energy Commission.

NEW PRODUCTS, MATERIALS AND SERVICES

—Literature—

National Carbon Co., Inc., New York, announces Model 6B Falling-Film type hydrochloric acid absorber as the latest addition to its line of Karbate equipment for processing and handling corrosive chemicals. The new absorber is a packaged unit complete with all accessories for automatic operation. The unit produces $2\frac{1}{4}$ to 16 tons of acid per day. Karbate absorbers are used to recover HCl produced in the manufacture of Freon, and to recover by-product HCl in the manufacture of Freon. Adoption of graphite for the construction of absorbers takes advantage of the material's high thermal conductivity and resistance to hydrochloric acid. Impervious graphite has a thermal conductivity between 50 and 80 BTU/sq.ft./ft./deg.F. Its chemical inertness to hydrochloric acid solutions includes all concentrations up to the boiling point and to dry or wet hydrogen chloride gases up to wall temperatures of 340° F. In the falling-film type absorber, the gas and liquid streams flow concurrently in the first stage and counter concurrently in the second. The new unit, which makes its own weight of 21 deg. Be. acid in less than 25 minutes, is 21½ feet high, and occupies a floor space of 2 feet, 11½ inches by 4 feet, 2½ inches. The range of application of the Model 6B can be extended by connecting two or more units in parallel.

Sinclair Refining Co. has developed a new rust-preventing compound. Known as RD-119, the newly discovered fluid is now being added to all Sinclair petroleum products as they flow through pipelines to distribution points. Under this process, all the oil company's products will contain an effective portion of the inhibitor. According to E. W. Ison, director of Sinclair's research program RD-119 provides, "an invisible monomolecular protective layer which prevents the metal surfaces from coming in contact with air and water, thus preventing rust and corrosion of such metals as steel, zinc, aluminum and brass." Patent applications covering development of the product have been filed. However, license agreements will be soon available making RD-119 obtainable for use by other firms.

Eagle-Picher Co. has available an 11-page bulletin entitled, Water Economy in Metal Primer Formulation, which discusses the use of more economical blue lead and red lead primer formulations for protection of iron and steel in atmospheric exposure. It covers briefly such subjects as the problem of the specifications engineer selecting the best paint system; the choice of vehicle composition which will give best results; surface preparation prior to painting; and the question of quick drying versus slow drying

paints. Detailed breakdowns of compositions, grinds and characteristics of suggested formulation are also presented. Copies of the bulletin may be obtained by writing Eagle-Picher Co., Technical Service Dept., Pigment Div., Cincinnati 1, Ohio.

A soft solder, with a 600° F. melting point, a very short plastic range and containing no tin has been announced by Soldering Specialties, Summit, N. J. The alloy was developed to meet the demand for a solder with a melting point midway between those of tin-lead solders and brazing alloys. Pre-market testing conducted by the company indicates the solder has a holding strength of 3500 psi, and a tensile strength of 5200 pounds, coupled with a high degree of ductility. These properties lead the manufacturer to expect the new product to be accepted as a substitute for silver solder.

Foster & Kester Co., Inc., Philadelphia 32, Pa., announce a plastic, Krylon. It is a transparent coating which is supplied in a self-contained compact sprayer. It can be applied to any surface by merely pressing the release button on the top of the can. Quick drying, it is said to leave a finish that retains the flexibility of the material to which it is applied, and possessing resistance to discoloration at high temperatures, water, alcohol, alkali, acids, mineral oils, grease and chemical fumes. The coating is removable by means of a special solvent available from the manufacturer.

Harvel 1-F black paint, used for many years as a coating for such

Orders for past issues of **CORROSION** have exceeded expectations and the Association has inadequate stocks of the following issues:

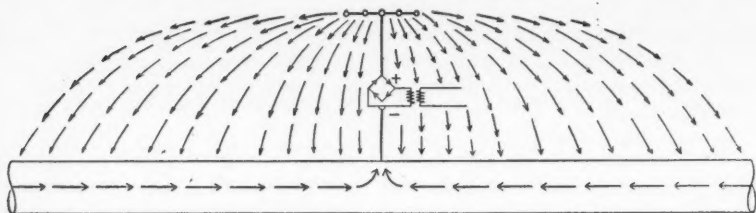
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|----------------|---------------|
| January 1947 | February 1948 |
| March 1947 | May 1948 |
| September 1947 | June 1948 |

Members having copies that they do not need or wish to retain are urged to send them to the National Association of Corrosion Engineers, 905 Southern Standard Building, Houston 2, Texas.

Until further notice fifty cents per copy will be paid for each of these issues.

items as laboratory furniture, cabinets and fume hoods, has been made available for other commercial and industrial finishing operations. The paint, a product of Irvington Varnish & Insulator Co., Irvington, N. J., is available in either air drying or baking formulations. It is said to be resistant to acids, alkalies, oils and solvents, and can be applied to wood, asbestos board, fiber board and synthetic stone.

Tornado, a combination blast gun which may be used for either sand-blasting or solvent spraying, is being manufactured by Engineered Products, Inc., 1224 Speer Blvd., Denver, Colo. Air operated, the portable device has no wheels to dress, motors to burn out nor shafts to break, and leaves no buffing marks, grooves, ridges, scuffs or uneven gouges on surfaces. It is particularly useful in reaching inaccessible places. Connected to any air line, interchangeable nozzles make the gun quickly adaptable for either blasting or spraying. Maximum air consumption is 9½ cubic feet per minute at 100 to 150 pounds pressure. It is equipped with a 3-pint container.



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Barrett* Coal-tar Enamels, because of their low moisture absorption under varying conditions of the soils, provide a constant, uniform and long-lasting resistance to electrical leakage.

Mechanically applied by modern methods, these coal-tar enamels assure the proper continuity of the insulation.

Electrical inspection improves the quality of application and the handling of pipe during construction and, together with a protective pipe coating of stable dielectric strength, makes cathodic protection economical.

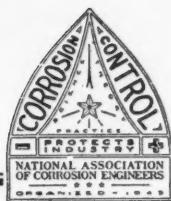
This combination permits the use of a minimum number of cathodic protection units, spaced the maximum distance, and a minimum investment in the complementary electrical protection. A dependable procedure when designing corrosion-proof pipelines.

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Corrosion Abstracts

ATMOSPHERIC CORROSION

Some Principles of the Corrosion of Metals and alloys in Moist Atmospheres. Georges Chaudron, *Rev. Met.*, 40, No. 7, 193-201 (1943).

Account of the theory of immersion corrosion phenomena, including intergranular attack.—MA.

CATHODIC PROTECTION

Our Billion-Dollar Side Show—for Managers Only. H. H. Anderson, Shell Pipe Line Corp., Paper before NACE Ann. Mtg., Chicago, April 7-10, 1947, *Corrosion*, 3, No. 6, 2-6 (News Section) (1947) June.

Discussion of the prevention of soil corrosion by cathodic protection. Principle explained.—INCO.

Contributions of Sir Humphry Davy to Cathodic Protection. I. A. Denison, *Corrosion*, 3, No. 6, 295-298 (1947) June.

An historical review.—MA.

Protection of the Pipeline of the Régie Autonome des Pétroles from Electrolytic Corrosion. Boyer, Paper before *Journées Metallurgiques d'Automne, Fall Metall. Conf.* sponsored by Soc. Française de Metallurgie and Comm. Tech des états de surface, (Paris), (Abst. in French) Oct. 6-10, 1947.

This network of pipelines is severely corroded by stray currents from the railroad. Insulating coatings are the basis of all effective, protection and comprise, 1) an inherent layer of bituminous paint, 2) a 2m/m thick asphalt layer, 3) a pre-impregnated band rolled in a single or double layer (asbestos + glass wool), and 4) an outer layer of asphalt. Cathodic protection is indispensable, two types being employed.—INCO.

Cathodic Protection of 138-KV. Lead-Sheathed Power Cables of the Los Angeles Department of Water and Power. Irwin C. Dietze, *Corrosion*, 3, No. 9, 432-442 (1947) Sept.

The main problems solved in designing

Abbreviations at the end of abstracts indicate source of abstract and contributor; and are as follows:

| | |
|-------|---|
| AER | Aeronautical Review, Institute of Aeronautical Sciences, Inc. |
| ALL | The Abstract Bulletin, Aluminum Laboratories, Ltd. |
| AWWA | Journal, American Water Works Association |
| BLR | Battelle Library Review, Battelle Memorial Institute Library |
| BNF | Bulletin; British Non-Ferrous Research Association |
| CALCO | Calco Chemical Division, American Cyanamid Corp. |
| CE | Chemical Engineering, McGraw Hill Publishing Co. |
| CEC | Consolidated Edison Co. of New York, Inc. |
| EW | Electrical World, McGraw Hill Publishing Co. |
| GPC | General Petroleum Corp. of California |
| INCO | The International Nickel Co., Inc. |
| IP | Institute of Petroleum |
| MA | Metallurgical Abstracts, Institute of Metals, London, Eng. |
| MR | Metals Review, American Society of Metals |
| NBS | National Bureau of Standards |
| RA | Refrigeration Abstracts, American Society of Refrigeration Engineers |
| RM | Revue de Metallurgie, Paris, France |
| RPI | Review of Current Literature Relating to the Paint, Colour, Varnish & Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. |
| UOP | Universal Oil Products |

cathodic protection for the system were the maintenance of the entire cable system at an adequate negative potential; providing a voltage step between cable sheaths and ground at each end of the line to pass fault currents but restrict drainage currents; and equalizing sheath potentials of other systems to prevent current at crossing points.—MA.

CHEMICAL CORROSION

Sulfuric Resistant Stainless. *Steel*, 122, No. 3, 90-92 (1948) Jan. 19; *Iron Age*, 161, No. 3, 83 (1948) Jan. 15; *Matl. & Meth.*, 27, No. 2, 80-82, (1948) Feb.

Durimet 20, formerly available only in cast form, is now to be had also in wrought form under the name, "Stainless 20." Composition includes 29% nickel-20% chromium-3% copper-2% molybdenum. Mechanical and physical properties are tabulated and corrosion data (including temperature effects, effects of contaminants, etc.) with sulfuric acid (H_2SO_4) are discussed and graphed. Uses and parts are mentioned. It is extensively employed in equipment for H_2SO_4 pickling of steel. Addition of ordinary salt or other chlorides, however, materially shortens life of parts. Alloy is especially resistant to nitric-sulfuric acid mixtures. Presence of any oxidizing agent will extend the limiting concentrations and temperatures for satisfactory service. Graphs give corrosion rate at various acid concentrations at 80° C., aerated. High corrosion rates result at concentrations over 50%. In common with other austenitic alloys, Stainless 20 is subject to carbide precipitation when heated in or cooled slowly through the sensitizing temperature range. Welded structures should be given a subsequent water quench form 2100° F. With spot welding, this is not necessary. Machinability compares with Type 302. Tensile strength 85,000,000 psi, elongation 35-50% in 2-in., Brinell hardness, 150-180. Available in bar stock, wire, strip, tubing and pipe. Carpenter Steel Co. produces alloy under licensing arrangements with Duriron.—INCO.

Mechanism of Pickling-Embrittlement of Steels—II. Behavior of Hydrogen Introduced into Annealed Extra-Mild Steel by Electrolysis or Acid Attack. P. Bastien, *Rev. Met.*, 42, 205-217 (1945); *British Absts.*, B1, 138 (1947) Apr.

Effects of hydrogen (H_2) absorbed during acid attack or electrolysis on basic Martin steels, Thomas steel, and Armco iron studied. For assessing the fragility of steels caused by H_2 absorption, a bend

test can be used, but it is recommended that the results be treated statistically and the mean of 40 values taken. The steels, when charged with H_2 and afterwards immersed in mercury at 18° C., evolved H_2 abundantly, the evolution being terminated in 1000 hrs. Important differences exist between steels of similar chemical composition but different manufacture. The majority of extra-mild steels in the annealed condition are highly permeable and therefore easily evolve H_2 ; consequently any brittleness almost completely disappears. Armco iron is only slightly permeable to H_2 and evolves only a little gas or retains its brittleness. Residual fragility is due to the presence of H_2 in the metallic structure and not to fissures or intergranular separations. Prolonged heating at 250° C allows successful expulsion of H_2 and alleviation of brittleness.—INCO.

Control and Maintenance of Electroplating Solutions. Parts II, and III. Nickel and Chromium. P. Berger, *Sheet Metal Ind.*, 24, 593-597 (1947); *ibid.*, No. 242, 1187-1192.

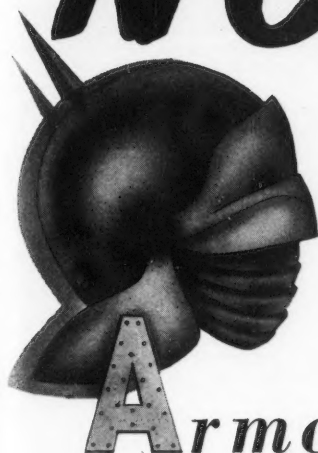
Control and maintenance of nickel and chromium solutions considered, reference being made to acidity, filtration, etc. It is stated that the most likely and frequent source of solution trouble in chromium plating is disturbed balance of the chromic acid (H_2CrO_4) sulfuric acid (H_2SO_4) ratio, which should be 100:1, weight for weight.—MA.

Microbiology and Corrosion. H. J. Bunker & T. H. Rogers, *Chem. & Ind.*, 59, No. 15, 257-258 (1940).

Behavior of metals in natural sea water may be entirely different to that in synthetic sea water, e.g. when mild steel corrodes in sea water, more hydrogen (H_2) is evolved than in the equivalent sodium chloride (NaCl) solution. In direct corrosion by hydrogen sulfide (H_2S), the corrosion product consisted of ferrous sulfide (FeS) where as in anaerobic corrosion by sulphate-reducing bacteria the reaction seemed to be: $4Fe + H_2SO_4 + 2H_2O \rightarrow 3Fe(OH)_2 + FeS$, so that only one-quarter of the corrosion products would appear as FeS. In practice, the proportion of FeS was higher because the organic matter present acted as a hydrogen donor as well as the metal, which gave cathodic hydrogen.—MA.

Corrosion Resistant Cements in the Plating Room. V. A. Curll, *Pennsylvania Salt Mfg. Co., Corr. & Matl. Prot.*, 4, No. 4, 19-20 (1947) July-Aug.

NOW...



Maloney Armored Insulated Couplings and Reducers are available to provide you with the ultimate in Cathodic Protection for your gas service lines and other pipe lines. These fittings are made of a fabric base Bakelite of the highest quality, locked inside of a cadmium plated steel jacket. This steel armor protects the insulating core against shipping hazards, damage during installation, and accidental abuse—even allows the use of a pipe wrench. Maloney Armored Insulated Couplings and Reducers are tested to 4000 p.s.i. and are suitable for working pressures up to 1000 p.s.i.—withstand temperatures up to 350° F.

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Handling of corrosive solutions in plating rooms in regard to their effect on pitting and erosion of floors, destructive attack in drains and developments of leaks with resulting loss of solution from pickling and plating tanks are discussed. How they can be overcome and why they are important in electroplating operations are outlined.—INCO.

Significance of Protective Film Formation in Corrosion of Lead. G. Schikorr, *Korros. u. Metallschutz*, 16, 181-187 (1940); *Brit. Absts.*, B1, 142 (1947) Apr.

The corrosion of lead in distilled water, in concentrated sulfuric acid (H_2SO_4), hydrochloric acid (HCl) and hydrobromic (HBr) in nitric acid (HNO_3), and in organic acids is discussed. The presence of chlorides (Cl^-) or sulfates (SO_4^{2-}) in distilled water reduces the corrosion of lead when carbon dioxide (CO_2) is absent, but increases it when CO_2 is present. In running, moderately hard tap water, lead corrodes very slowly after a year.—INCO.

Automobile Chassis Corrosion. *Chem. Eng. News*, 26, No. 1:56 (1948) Jan. 5.

Controlling chassis corrosion with a mixture of sodium chromate or sodium dichromate with de-icing salt has been tested by Goodyear engineers at Akron, Ohio. Results indicate mixture will inhibit brine corrosion of auto chassis and fenders caused by the use of salt on icy roads and at the same time slightly toughen natural and synthetic rubber compounds in the tires. These tests were conducted at 100° F. with samples immersed for as many as 504 hours in the salt-chromate baths. The yellow sediment left on the fenders and chassis can be washed off readily.

COATINGS

Abrasion Tests on Lacquers and Paints. R. S. Dantuma, *Verfakroniek*, 16, 36-37, (1943).

Tests used in different countries are reviewed and compared. The tests fall into three main groups: tests in which the paint film is sprayed or centrifuged with sand or fine carborundum; tests in which the paint film is bombarded with shot or coarse carborundum; tests for road paints in which the paint film is subjected to the action of a small revolving rubber-tired wheel. In the first class of tests control of the uniformity of the size of the abrasive particles is shown to be important.—RPI.

Discoloration and Deterioration of Paints Due to Fungi. *Fette u. Seifen*, 49,

No. 1, 60-62 (1942); *Chim. et Ind.*, 50, No. 2, 43D, (1943).

A warm, wet climate, diffuse light and resting places for dust are favorable to the growth of moulds. Casein provides food for the moulds. Fungicides are added as an emulsion rather than as a solution. A list of fungicides is given. The blueing of green paints containing chrome yellow has been attributed to porianxantha, which produces oxalic acid. This reduces $PbCrO_4$ forming lead oxalate.—RPI.

Temporary Protective Coating for Metals. *Corros. & Matl. Prot.*, 4, No. 6, 27 (1947) Nov.-Dec.

For use on stainless steel, chromium plate, and aluminum, Spraylat compounds give a film coating that adheres strongly to the metal, permitting all machining operations to be performed; yet the film can be removed by a steady pull when desired. The solutions contain 3.8 lbs. of dry solids per gal. They are water dispersions of film forming materials and do not contain volatile solvents. Thus they do not present fire hazards or a toxic condition in spraying. A film thickness of 0.003 in. is satisfactory. Mfg. by the Spraylat Corp.—INCO.

Protective Coatings. *Anon. Chem. Eng.*, 54, No. 5, 242-244+ (1947).

Report on the resistance to the action of acetic acid (at various concentrations) and Cl_2 of a series of proprietary synthetic coating materials. Baked phenol/ CH_2O resins are not recommended where exposure to wet or dry Cl_2 is experienced. Vinylite resins may be used at 100° F.

Chlorinated Rubber—Basis of New Protective Coating. *Anon. Chem. Age*, 56, No. 1455, 707.

Chlorinated rubber solution containing finely divided metallic zinc provides an effective coating for iron and steel work in a corrosive atmosphere. Concrete treated with this solution is rendered waterproof and has good resistance towards acids and other corrosives.

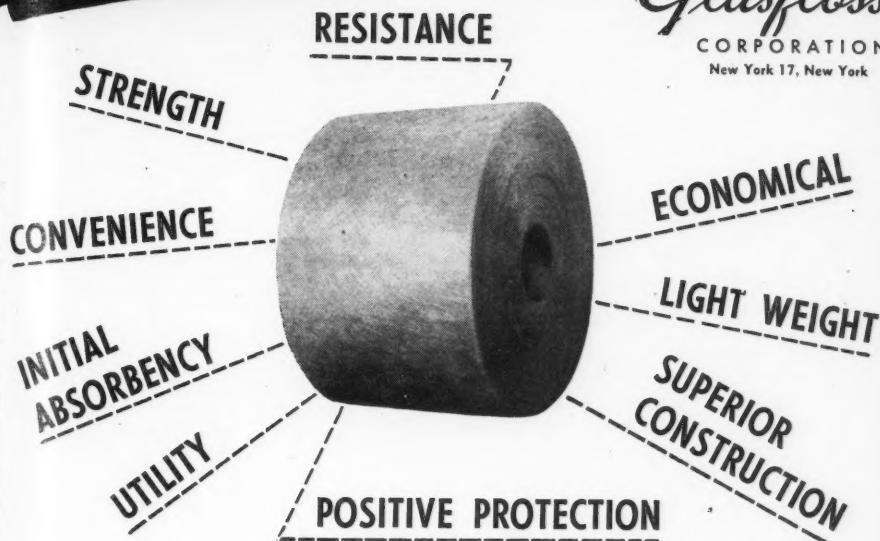
Neither Time Nor Tide ... Bakelite Rev. 19, No. 3, 3-8 (1947) Oct.

Coatings based on Bakelite 100% phenolic resins were applied to many types of submerged metal surfaces in the Ohio river and its tributaries, in the Mississippi river, in Florida waters, in the Gulf of Mexico, in the Great Lakes and in western coastal waters. Panels show results of one year total immersion. Coatings based on Bakelite resins have been

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written into finishing specifications in use by lock and dam engineers in charge of the Pittsburgh, Mississippi and Chicago engineering areas and Tennessee Valley Authority, and are specified for many federal, state, county, municipal and industrial applications. Tests are fully described, with results from both fresh and salt water. Results show 100% phenolic resin varnish vehicles superior to the alkyd vehicle in durability and water resistance, and superior to vehicles combined of phenolic and alkyd resins. Effectiveness of various Bakelite resins is compared.—INCO.

Eronel Plastic Thermo-Dip N.S. Protects Machine Tools and Gears. Anon., *Am. Mach.*, 91, No. 25, 158 (1947) Dec. 4.

Thermo-dip N. S., a hot-melt compound for protecting tools, gears, and parts from corrosion, abrasion, shipping and handling, is said to be resistant to salt water, high humidity, maintains its flexibility for long periods, is removed by stripping and can be reused. Mfg. by Eronel Inds., Los Angeles.—INCO.

Application of Paint to Metallic Surfaces. J. N. T. Adcock, *Sheet Met. Ind.*, 24, No. 247, 2227-2232 (1947) Nov.

Brief survey of modern methods. Describes pretreatments, application and stoving, with details of spraying, dipping, flow-coating, roller-coating and allied electrostatic techniques. Description of types of convection and radiant-heat ovens is included.—BNF.

German Aircraft Protective Coatings. H. L. Acker, *Off. Pub. Bd., Rep. PB. 22, 831* (1945) 15 pp.; *NPVL Absts.*, No. 118, 185 (1946).

Covers research, development and investigations for improved protective coatings for aluminum, magnesium, steel, fabric and other aircraft components carried on by the German Air Ministry. Information is based on checking German specifications, examination of aircraft and component parts, and interrogation of engineering and production personnel. The specification for quality of German military aircraft was set up in 1933, with adjustments and improvements up to 1938. Specifications were very rigid and in many respects followed U. S. procedure. The steel was of high quality, properly treated and plated before assembly. Alclad and anodizing were prime requirements. All surfaces, interior and exterior, required high quality primer and finish coat of an alkyd or phenolic base. The quality of

these finishes dropped rapidly after 1938 and continued dropping until the end of the war.—RPI.

Protective Wire Coating Production Accelerated. Charles W. Ange, *Ind. Gas.* 26, 13-14 (1947) Oct.

Describes application of lead-alloy coating known as Okoloy to copper conductors by The Okonite Co., Passaic, N. J.—BLR.

First Report on Investigation of the Conducting Properties of Films, Pigmented With Copper. R. Benemelis & others. *Off. Pub. Bd., Rep. PB. 23, 127, 26 pp.* (1945); *NPVL Absts.*, No. 118, 184 (1946).

Some evidence exists that organic films containing metallic copper pigment may sometimes be expected to perform similarly to a metallic conductor. The present investigation of anti-fouling paints was designed to uncover evidence to clarify this point of view. A number of experiments are described in which efforts have been made to study the electrical conductivity of anti-fouling paint compositions covering a wide range of pigment volumes. The data indicate that at high pigment volume the conductivity of the film is of a sufficiently high order to accelerate the corrosion of steel to which it is coupled through a metallic conductor. Further evidence is presented to show that paint films which provide cathodic areas blister and fail more rapidly than non-conducting films. Additional experiments are recommended to expand this investigation to include Cu_2O paints. Curves and photographs.—RPI.

Mildew Problems of Interest to Paint, Varnish and Lacquer Manufacturers. P. G. Benignus, *Am. Paint J.*, 31, No. 28, 304- (1947).

Review of fungicides evolved for use in all types of protective coatings, and also for wood preservation. Causes of mildew growth are outlined, and it is suggested that the use of synthetic materials in lacquer and varnish manufacture will inhibit fungal growth, through the use of fungistatic agents is desirable. Of new fungicides developed, copper & hydroxy-quinoline and zinc pentachlorophenate are promising.

Methods of Applying Wood Preservatives. Part I—Non-Pressure Methods. J. Bryan, *Forest Prod. Res. Rec.*, No. 9, 13 pp. (1946); *Build. Sci. Absts.*, 19, No. 7, 20 (1946).

In the revised edition of this report

PROTECTIVE COATINGS?

That is the problem... here is the solution!

Typical Chemical Industry Uses

| COATING | DESCRIPTION AND USES | CHARACTERISTICS OF EXPOSURES |
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| #33 | A single solution, general maintenance coating for concrete and metal surfaces exposed to corrosive fumes, condensation and spillage of dilute acids, alkalies and salts. Pipe lines, storage tanks, structural steel, galvanized iron, fume ducts, blowers, hoods, fans and Zeolite water softening units. | General plant exposure to fumes and spillage of acids, alkalies, salts and many other corrosive chemicals. Exterior: weathering, salt air, chemical fumes. |
| #23 | A three component system recommended as an interior lining for steel and concrete storage tanks, tank cars, and process vessels. Prevents corrosion of the surface. Prevents iron or calcium contamination of the contained product. Resists abrasion, non-toxic to food products, easy to clean. | Various salts, dilute acids, alcohols, glycerol, beverages, and steam. |
| #44 | A three component coating recommended for use in exceptionally severe conditions. Specially formulated to resist acids at higher temperatures and concentrations. Used for lining sodium hypochlorite tanks, hydrochloric acid tanks, sulfuric acid tanks, liquid fertilizer and distribution tanks. | Sodium hypochlorite, ammonium hydroxide, and other caustics. |
| #31 | A three component system recommended for constant immersion at temperatures up to 180° F. Excellent for dilute or concentrated solution. Used for lining stationary tanks, clarifiers and thickeners, ammonium nitrate and potassium chlorate storage tanks and equipment. | Caustic soda, calcium hydroxide, potassium chloride, salt solutions, ammonium nitrate, ammonium sulfate, potassium chlorate. |
| #55 | A three component system recommended for constant immersion in concentrated salt or alkali solutions at temperatures up to 230° F. Particularly satisfactory for strong alkalies, such as 70% sodium hydroxide. No. 55 is not recommended for food products. | Hot caustic soda solutions, calcium and magnesium chloride, salt solutions; potassium chlorate. |



Free Corrosion Manual

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AMERCOAT Protective Coatings are remarkably versatile in their inherent chemical resistance and non-contaminative properties. Yet, no single protective coating formula can provide maximum surface protection under all conditions, without compromise on some desirable quality. Therefore, AMERCOAT formulas are designed for specific uses in industry. They range from specialized linings for chemical and food tanks to general maintenance coatings for metal or concrete surfaces. Each provides maximum protection in its field.

Chemically inert, tougher and much more durable than conventional paint, these remarkable AMERCOAT Coatings are easily applied by brush or spray to metal, concrete or wood. They dry quickly and are extremely resistant to abrasion.

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full description is given of the various non-pressure methods of applying preservatives, e.g., toxic chemicals, to timber, indications being given of the degree of protection afforded by each type of treatment and of its applicability to different kinds of timber. The rate of penetration of creosote into Scots pine at different temperatures is shown graphically.

Pigmentation of Protective Paints. F. Von Artus, *Korros. u. Metallschutz.*, 17, No. 10, 361-3 (1941); *Chim. et Ind.*, 47, No. 3, 406 (1942).

Discusses formulation of paints for the protection of both metals and stone.

Must Iron Rust? Anon. *Tin and Its Uses*, No. 18, 5-8 (1947) July.

Usefulness of various precoatings before painting iron and steel surfaces is evaluated. Zinc is extremely unsatisfactory under paint, whereas tin is effective. Specimens are shown which were given thin and thick phosphate coatings, and tin coatings, 0.00005 in. thick, under paint and subsequently exposed 600 and 4560 hrs. to light and accelerated weathering. The various advantages of using tinned stock are enumerated.—INCO.

No Electric Current Used in New Method of Plating Nickel and Cobalt on Metal Surface. Anon. *Steel*, 121, No. 4, 84+ (1947) July 28.

Electroless plating, a process for plating nickel and cobalt on metal surfaces without the use of electric current, was developed by A. Brenner & G. E. Riddell of the Natl. Bur. Stds. The coating process is brought about by chemical reduction of a nickel or cobalt salt with hypophosphite in hot solution. The reduction occurs only on the surface of the immersed metal, producing an adherent coating of 93 to 97% purity. The deposits produced are of good quality—sound but brittle, and generally bright. Unusual feature of the process is the catalytic initiation of the reaction by the following metals: iron or steel, nickel, gold, cobalt, palladium, and aluminum. Once started, the reaction continues at the metallic surface and only rarely occurs in other parts of the bath. For this reason, the container must be of glass, plastic, or other noncatalytic material. The process is particularly applicable to the plating of recesses, irregular-shaped objects, and enclosed areas such as tubes.—ALL.

Symposium on Modern Metal Protec-

tion. *Steel*, 121, 90-91+ (1947) Nov. 3.

Presents condensed versions of seven papers presented at Cleveland meeting sponsored by ACS, AICE and ECS. They are as follows: Selection of Protective Coatings for Metals, by K. G. Compton; Organic Coatings for Corrosion Protection, by George W. Seagren; Synthetic Rubber Derivatives as Corrosion Resistant Coatings, by J. B. Martin; Protective Coatings for High Temperature Applications, by W. N. Harrison; Corrosion Resistant Chemical Equipment of Stainless Steel, by W. R. Meyer and H. L. Maxwell; Corrosion Resistance of Nickel Base Alloys and Applications in Processing Equipment, by R. B. Long; and Some Notes on Corrosion Behavior of High Nickel Alloys and Stainless Steels by H. O. Teeple.—BLR.

The Struggle Against Corrosion by Application of Films of Paint. G. Kühnberg, *Kolloid-Beih.*, 52, Nos. 8-10, 277-402 (1941); *Chim. et Ind.*, 46, No. 3, 333 (1941).

Corrosion protection conferred by a paint is due to its prevention of all contact with moisture (water or water vapor), or the suppression of electrochemical corrosion reactions when the moisture restriction is not absolute. The protective action of red lead/linseed oil is increased by the addition of barytes or blanc fixe, but zinc-oxygen and whitening have the reverse effect. Chlorinated media (chlorinated rubber, polyvinyl chloride, etc.) are inert and have certain advantages, but tend to become activated by exposure to moisture, leading to deleterious results.—RPI.

Plating Molybdenum, Tungsten, and Chromium by Thermal Decomposition of Their Carbonyls. J. J. Lander & L. H. Gerner, *Metals Tech.*, 14, TP. 2259, 42 pages (1947) Sept.

Describes the plating of molybdenum and tungsten, and of compounds and alloys of these metals, by pyrolysis of the carbonyl vapors. Chromium has also been plated in this manner, but the results have been much less satisfactory. The apparatus, procedures, and properties of the products are described in detail. Also describes the plating of magnetron rings for test purposes, and the design of a machine for conducting this operation on a commercial basis. 15 refs.—BLR.

Metallization with Aluminum. C. Draper, *Light Metals*, 10, No. 110, 124-1 (1947); correspondence, *Ibid.*, No. 112, 1 (1947).

A lengthy discussion of current tech-

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niques and apparatus for the coating of metallic and non-metallic articles with aluminium. Mechanical, dipping, and calibrating methods are dealt with, and spraying methods are described at length; uses of sprayed coats are also discussed. Corrosion findings are considered, as well as resistance to high-temp. oxidation. The use of aluminium in paint, electrodeposition, evaporation, and sputtering is then reviewed, together with its application to mirrors.—MA.

Oxidation Treatments of Aluminum and Magnesium. André Dumas, *Rev. Met.*, **40**, No. 10, 310-318 (1943); *Ibid.*, No. 11, 343-350; *Ibid.*, No. 12, 374-377.

An account of the production of protective films on aluminium and magnesium by immersing in chromate or phosphoric acid baths, utilizing galvanic action, and anodic oxidation. The properties of the film formed are described. A description is given of the Brytal process of electrolytic brightening.—MA.

Chemical Reaction in Metal Protective Paints. E. J. Dunn, Jr., Natl. Lead Co., Paper before Symp. on Corrosion Resistant Paints, Brooklyn, May 4, 1946. *Paint, Oil & Chem. Rev.*, (1946) July 25; *Corrosion*, **3**, No. 8, 374-382 (1947) Aug.

There are many formulations for paints because the drying and weathering of a paint film is a complex subject. Lead and zinc soaps, chemical determination of soap formations, acid number determinations, and water permeability of soaps are discussed.—INCO.

Coating With Metals by Immersion. Eugene Dupuy, *Rev. Met.*, **41**, No. 7, 208-216 (1944).

The conditions leading to the covering and protection of metal surfaces against corrosion, together with the processes of tinning, galvanizing, and coating with lead, cadmium, aluminium, and mercury, are reviewed.—MA.

Coro-Gard. *Oil & Gas J.*, **46**, No. 41, 111 (1948) Feb. 12.

Coro-Gard, a new anti-corrosion protective coating prevents corrosion of steel tanks in sour-crude fields for 2 years. It has a synthetic-resin base, a powdered micro-gray pigmentation, and a solvent consisting of methyl-isobutylketone and butyl acetate, 1:1 by volume. Black variation is achieved by adding 2% carbon black. Solids content is approx. 26%. Viscosity corresponds to thin syrup, 3-5 at

80° F. on a 26 wire of MacMichael viscosimeter. Application is by conventional spray, brush or sloop, and involves no activators, heat cures, or primers. Announced by Minnesota Mining & Mfg. Co.—INCO.

Anti-Corrosive Pigments. *Paint Mfr.*, **17**, 55-57 (1947) Feb.; *Metals Rev.*, **20**, No. 4, 22 (1947) Apr.

Discussion of pigments used in paints for protection of steel surfaces, at a meeting of the London Section of the Oil and Color Chemists' Association on Nov. 13, 1946.—INCO.

Successful Painting Requires Careful Surface Preparation. New Jersey Zinc Co., *Paint Prog.*, **6**, No. 3, 8-9 (1947).

A general discourse on the preparation of large surfaces, e.g., ships, for painting.—RPI.

Continuous Hot Galvanizing of Strip. E. A. Matteson, *Iron & Steel Eng.*, **24**, No. 3, 61-62; Discussion 63-66 (1947).

Brief review of modern continuous hot galvanizing plants and processes.—MA.

Synthetic Rubber Derivatives as Corrosion Resistant Coatings. J. B. Martin, Hercules Powder Co. Paper before Sym. on Modern Metal Protection, Cleveland, Oct. 1947; *abstr. Steel*, **121**, No. 18, 126 (1947) Nov. 3.

Chlorinated rubber based paints are resistant to almost all chemically destructive agents as well as dampness, vapors and various fumes, and possess a high degree of water impermeability and a very low degree of water absorption. Due to their thermoplastic character, the paints are not suitable for continuous exposure to liquids above 140° F. or to dry heat above 160° F. Chlorinated rubbers especially adapted for the manufacture of industrial maintenance paints are quick drying enamels, which have many applications, e.g., protection of structural steel and equipment in oil refineries to resist acid fumes. Alkyd finishing materials formulated with 20% chlorinated rubber are also utilized.

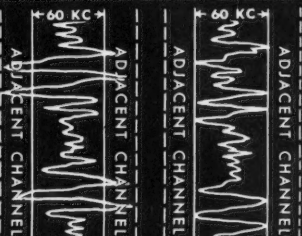
Full Automatic Hot Zinc Galvanizing Tanks. Raymond F. Lodford, *Iron Age*, **160**, No. 5, 56-60 (1947).

Explains the advantages of fully automatic methods of hot zinc galvanizing and describes several examples of "conveyORIZED" tank-galvanizing installation including the make-up and other characteristics of baths for mechanical operation.—MA.

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Protection of Bright Tools Against Rust (with Lanoline). O. Kantorowicz, *J. Sci. Instruments*, **24**, No. 4, 109 (1947).

A note. Bright tools can be prevented from rusting by painting with a solution of lanoline. If benzene is used as solvent, difficulties are encountered owing to the condensation of moisture on the surface, the relatively heavy moisture on the surface, the relatively heavy moisture then sinking through the surface. This difficulty has been overcome by using carbon tetrachloride as a solvent. Detailed instructions for protecting tools are given.—MA.

Flame Spraying by the Powder Pistol. W. D. Jones, *Sheet Metal Ind.*, **24**, No. 238, 375-382; discussion, No. 240, 781-783 (1947); (condensed) *Engineering*, **162**, No. 4237, 297-299 (1947); *Found. Tr. J.*, **81**, No. 1591, 157-158 + (1947).

A paper presented to the Sheet and Strip Metal Users' Technical Association. Conditions governing process are discussed, and various metallic and non-metallic protective coatings applied by the method are reviewed.—MA.

Protective Coatings for High Temperature Applications. W. N. Harrison, Natl. Bur. Standards. Paper before Sym. on Modern Metal Protection, Cleveland, Oct. 7, 1947; abstr. *Steel*, **121**, No. 18, 126-128 + (1947) Nov. 3.

Development of a new type of ceramic coating for metals from a special grade of calcined aluminum oxide by the National Bureau of Standards is described. The coatings are highly resistant to chipping under repeated severe thermal shock, protect metal against oxidation during prolonged exposure in air at temperatures up to 1250° F., remain free from the cracking and blistering common to ordinary porcelain enamels, and have a mat surface which does not show highlights. Industrial uses include the coating of automobile mufflers and tail pipes, industrial furnace parts, such as baffle plates, and parts for heat exchangers.

Comprehensive Report on DVL Light Metals Underwater Coating Methods. Tests Held in 1937-38. *Off. Tech. Serv. Report PB*, 38996, 8 pp. (1938); *NPVL Abstr.*, No. 124, 179 (1947).

Twenty-one coating systems for the underwater protection of light metals were examined. Eloxidising secured an increase in durability.—RPI.

Recommendations for Phosphate Coatings as a Basis for Painting Steel. *British*

Standards Institution. PD, 539, (1946).

An interim statement of methods of testing and depositing phosphate coatings.—RPI.

Report of Committee B-8 on Electrodeposited Metallic Coatings. *ASTM Preprint No. 15*, 7 pages (1947).

Gives results of atmospheric exposure tests on copper-nickel-chromium deposits on high-carbon steel and on electroplated lead coatings on steel.—BLR.

General Instructions for Tropicalization of Communications Equipment. *U. S. Army Air Forces Tech. Order* 16-1-41; *Off. Pub. Bd.*, Report **PB**, 41, 942, 26 pp. (1945); *NPVL Abstr.*, No. 121, 64 (1947).

The treatment outlined in this publication consists essentially of the application of a moisture-resistant and fungicidal insulating lacquer. The report considers cause and effect of moisture and fungi, remedies, basic procedure for treatment, facilities for tropicalization, and materials for treatment.—RPI.

Japanese Ships, Miscellaneous Items. *U. S. Naval Technical Mission to Japan, B.I.O.S. Report No. B.I.O.S./J.A.P./T.R./* 612, 5 pp. (1946).

A substitute process for Parkerizing involved the immersion of the article to be protected in a 10% aqueous solution of arsenic acid (H_3AsO_4) containing 1.45% nitric acid (HNO_3). Some other substitute processes are also mentioned. Pre-war paint formulation was on conventional lines; during the war the use of red lead was restricted and the final emergency anti-corrosive undercoat for ships was pigmented with a mixture of lead chrome (10-12%) and iron oxide (remainder).

Care of Galvanized Roofing. *Agriculture Extension Service, Iowa State College, Pamphlet* 114 (1946); *Rail. Eng. Abstr.*, **11**, No. 7, 195 (1947).

A leaflet giving advice on points to be observed in repairing old roofs which have begun to leak; on the kinds of rust-inhibitive paints to be used when failure of the zinc coating is first seen, with special notes on zinc dust/zinc-oxide paints, and on the preparation of the surface for painting, and the application of the paints.—RPI.

Science and the Canning Industry. *Food Mfr.*, **22**, No. 8, 345-8 (1947).

The scientific development of the canning industry is traced from 1810 to the present day. Reference is made to the

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importance of synthetic resin and other varnishes in protecting the cans from attack by the food.—RPI.

Baked Phenolic Resinoid Coating. U. S. Bureau of Ordnance, *Navord Spec. 2517; Report PB. 36803*, 5 pp. (1942); *Paint Notes*, 2, No. 3, 91-92 (1947).

This coating shall contain heat-hardening phenolic resins, pigments of the earth type and softening agents. It shall contain no drying or non-drying oils or cellulose material. The thinner shall be alcohol or a mixture of alcohols and acetates or a mixture of esters, alcohols and hydrocarbon solvents. The finished coating shall have a uniform film thickness of 0.003-0.005 in. Application and test methods are described. The coating is intended to prevent surface corrosion in the interior of pressure vessels.—RPI.

Metal Spraying and Industrial Economy. H. W. Greenwood, *Metallurgia*, 37, No. 218, 60 (1947).

A review of the uses of sprayed coatings, particularly of zinc, and of polythene.—MA.

Mechanical Properties of Chromium Diffusion Coatings. N. S. Gorbunov, I. D. Yudin, & N. A. Izgaryshev, *Compt. rend. (Doklady) Acad. Sci. U.R.S.S.*, (In English) 55, No. 5, 415-417 (1947).

Micro-hardness of chromium diffusion coatings was measured on pure iron, steel, and cast iron after a preliminary 6-hr. treatment at 1000° C. for iron and steel, and 900° C. for cast iron. The results show that micro-hardness increases rapidly with an increasing carbon content, ranging from a value of 200 for pure iron to 1900 for cast iron.—MA.

Rust Prevention on (Food) Cans. R. A. Gillie, *Food*, 16, 81-84 (1947); *Brit. Absts.*, B1, 218 (1947) July.

For the prevention of rusting of the exterior of food cans in store, the cans are washed with an alkaline detergent containing sodium dichromate before lacquering. The concentration is given for trisodium phosphate, heximeth phosphate, sodium silicate, and sodium hydroxide respectively, where timplate and mild steel (material of tank) are in contact. This alkali-chromate washing treatment is successfully carried out in the retort during sterilization.—INCO.

Coatings for Eloxidised Light Metals. H. Giehmann, *Off. Tech. Serv. Report PB*, 54448, 18 pp. (1937); *NPVL Absts.*, No. 124, 180 (1947).

Since the supply of lanolin for the anti-corrosive coating of eloxidised metals was insufficient, a series of grease and varnish type impregnating agents was developed and examined. Varnish types were preferable. If the outer surfaces of aircraft are also eloxidised, one-coat, durable varnishes can be applied and will adhere satisfactorily.—RPI.

Concerning Electrodeposited Oxide Layers on Aluminum. Fritz Liecetti & W. D. Treadwell, *Helvetica Chimica Acta*, (In German) 30, No. 5, 1204-1218 (1947).

The growth and analytical content of oxide films on aluminum during anodic oxidation in sulfuric and oxalic acid solutions, respectively, with and without bath agitation, were investigated. Results are charted and tabulated and an equation is deduced from the curves for the film from the sulfuric acid bath which shows that the sulfate-ion content of the film decreases exponentially with its thickness. In oxalic acid, no appreciable solution of the film takes place.—BLR.

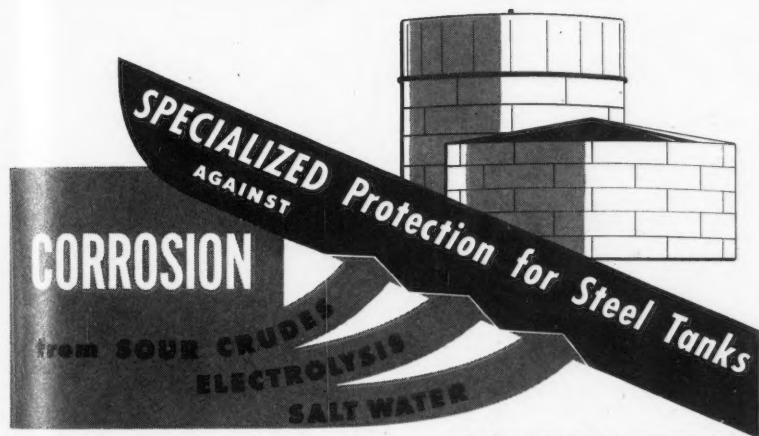
CONSTRUCTION MATERIAL

Cast Heat-Resistant Alloys of the 26% Chromium-20% Nickel Type—Part I. H. S. Avery & C. R. Wilks, American Brake Shoe Co., Paper before ASM 29th Ann. Conv. Chicago, Oct. 18-24, 1947; *ASM Preprint* No. 16, 49 pp. (1947).

Mechanical properties at room temperature, stress rupture and creep strength from 1400°-2000° F., thermal expansion, resistance to carburization and corrosion by hot gases are given for the wrought and cast HK alloy (26% chromium-20% nickel). Comparisons with wrought 310 stainless steel at the 0.1 carbon level indicate that elevated temperature strength of the cast material is between that of solution heat treated and of normalized wrought specimens. The cast alloy at 0.3 carbon is considerably stronger. Base line properties at 0.3 carbon are presented after surveying 18 compositions by stress-rupture tests to determine probable scatter bands. The HK grade is the preferred cast alloy where general hot gas corrosion resistance is required, and is well suited for carburizing service when fortified with about 2% silicon. Sensitivity is due to carbon content, and decarburization near 2000° F. may be more serious than metal loss by scaling. 37 ref.—INCO.

Some Notes on Corrosion Behavior of High Nickel Alloys and Stainless Steels. H. O. Teeple, INCO, Paper before Sym.

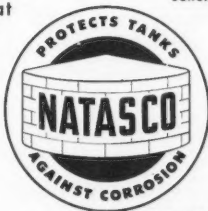
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on Modern Metal Protection, Cleveland, Oct., 1947; abstr. *Steel*, **121**, No. 18, 134 (1947) Nov. 11.

Factors influencing the corrosion resistance and service life of stainless steel alloys include temperature, presence of oxidizing agents, air velocity or agitator, selection of inhibitors, development of concentration cells and stress relief heat treatment. Temperature variations within the range 30-90° C. have little effect on the corrosion resistance of stainless steel in nitric acid, as is indicated by tabulated data.

Corrosion. Mars G. Fontana, *Ind. & Eng. Chem.*, **39**, 91A-92A (1947) Dec.

Describes corrosion resistance, mechanical properties, and some uses of a heat-hardenable 18-8 stainless steel known as Stainless W, and produced by Carnegie-Illinois Steel Corp. Nominal composition is as follows: 17% chromium, 7% nickel, 0.7% titanium, 0.2% aluminum, 0.07% carbon, 0.5% silicon, 0.5% manganese, 0.01% phosphorus, and 0.01% sulfur.—BLR.

High Pressure Oscillating Shower Pipes and Stainless Steel Plates With Rotary Screens. F. F. Frothingham, Bird Machine Co., *Paper Tr. J.*, **124**, No. 22, 118-120 (1947) May 29.

Stainless steel screen plates are used in the Bird Oscillating shower pipe and rotary screen assembly. Over 100 sets of the plates are in operation. A combination of stainless steel plate construction assembly and cylinder construction resulted in a product which operates for a long period without sign of wear. Corrosion resistance is also valuable. Experimental work was done at Magnus Metal Co. and the product is known as Hardy Type Stainless Steel Plate. Screen is shown. Stainless composition not given.—INCO.

FUNDAMENTALS

The Theory of Corrosion Phenomena. XVIII. The Basis of the Local Element Electrochemical Explanation of Corrosion Processes. W. J. Müller, *Korros. u. Metallschutz*, **16**, Nos. 1-2, 1-10 (1940).

The local surface cell theory of corrosion developed by author is discussed together with the relationships which exist between the c.d., e.m.f., and resistance of those cells in which polarization occurs at the anode and cathode.—MA.

Comparison of the Principal Methods of Microgeometric Control. G. Michalet, *Journées des Etats de Surface* (Paris) **124-134**; discussion, 134 (1945).

A general review of methods of measuring the microgeometry of surfaces, with particular reference to those used at the French Central Armament Laboratory. Methods discussed include the photography of the image of an illuminated slit reflected from the surface under examination, the assessment of the height of irregularities from the shadows cast under oblique illumination, interferometric methods, and methods depending on the diffusion of light for assessing the quality of polished surfaces. The principles of the apparatus used are described and illustrated by diagrams and photographs. It is stressed that the methods used must depend on the phenomena to be assessed, and that no single apparatus will give all the data needed.—MA.

Effect of Crystal Orientation on the Hot Oxidation of Iron and Copper. Jacques Benard & Jean Talbot, *Compt. rend.*, **225**, No. 9, 411-413 (1947).

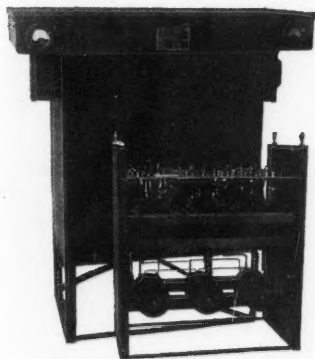
The investigations previously carried out on the variation of the rate of oxidation in air at 850° C. of polycrystalline iron after various mechanical treatments (*Rev. Met.*, **44**, No. 3-4, 82 1947) were extended to copper. In the case of rolling, it was found that the rate of oxidation of iron and copper increases proportionately with the reduction in area. X-ray examination of the deformed metal showed that this variation is connected with the appearance of an oriented structure and is independent of the sub-division of the crystals and lattice disturbance. A study of the oxidation of large single crystals was required to interpret these facts. Single crystals of copper some 10 cm.² in area were therefore prepared, their crystallographic orientations determined by Laue diagrams, and the isothermal oxidation-time curves at 900° C. plotted using a Chevenard thermo-balance. It was shown that the effect of the deformation of copper and polycrystalline iron on the susceptibility of these metals to oxidation finally results in the unequal rate of oxidation following the crystal orientation. The origin of the anisotropy thus revealed might be due to the difference between the true rates of oxidation of the metallic crystal faces or to unequal rates of diffusion of the elements of the reaction (metal and oxygen) across the oxide already formed on each of them. The second alternative appeared the more likely from previous published investigations, and was confirmed in the case of copper by a study of the orientation of the oxide crystals in the grains. A new fact discovered was that the oxidation-temp. curves show

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in the first few minutes a perfectly straight line portion before taking a parabolic form. The slope of this line represents the true rate of oxidation of the metal before it is retarded by the effect of diffusion.—MA.

High-Temperature Oxidation. H. M. McCullough, *Eng. Expt. Station News, Ohio State Univ.*, 19, No. 5, 38-41 (1947) Dec.

An investigation of the mechanism of oxidation of stainless steel (chromium and chromium/nickel).—BNF.

Tracers in Metallurgy. Julius J. Harwood, *Nucleonics*, 2, 57-61 (1948) Jan.

Reports on use of radioactive-tracer techniques as applied to metallurgical problems by two university laboratories. The major study was that of diffusion processes in the solid and liquid states.—BLR.

Electron Diffraction Studies of Compounds Adsorbed on Metal Surfaces. N. Hackerman & H. R. Schmidt, Univ. of Texas, Paper before ACS Southwest Regional Mtg., Houston, Texas, Dec. 12-13, 1947; *Petro. Ref.*, 27, No. 1, 142 (1948) Jan.

Investigation of the mechanism of corrosion inhibition by polar organic substances. Electron diffraction patterns of adsorbed compounds were obtained to learn more about the nature of their attachment and structure. The surfaces were treated by smearing, melting, or placing a drop of a solution on polished steel specimens. Three distinct types of patterns were obtained and calculations showed that they were due largely to the hydrocarbon structure. The firmness of the adherence was determined qualitatively by obtaining a pattern, washing the steel specimen with solvent, drying, and exposing to the beam again.—INCO.

GENERAL CORROSION

Metallurgy Research Drives to Meet New Economic Needs. E. S. Kopecki, *Iron Age*, 161, No. 1, 198-207 (1948) Jan. 1.

This review of research in metallurgical fields includes several processes not yet publicized. Use of radioactive tracer isotopes in the study of fundamental metallurgical problems, including corrosion, is discussed. Studies in the oxidation of iron show that kinetics and mechanics of oxidation can be correlated with structures of phases in scale. Work at Westinghouse Res. Lab. aims to determine diffusion of carbon in alpha iron and perhaps some alloyed ferrites, including nickel and cobalt. Great interest centers in continuous

casting processes, especially development of this process for carbon and alloy steels. The Hopkins process of melting metals or alloys in a mold under slag blanket has been applied to increase ingot yields in carbon, stainless, and high-speed tool steels as well as high temperature alloys. Employing a special flux and nonconsumable electrode, elimination of ingot pipe has resulted in raising yields to 90-93%. Oxygen in steel making held a prima donna role during year and is discussed, as well as vacuum melting and heat treatment, use of carbon black linings to improve blast furnace operations, powder scarfing of stainless steels (illustration) the new castable refractory (Kaceast) which stands 7000° F., and a new extrusion molding process useful for all standard nonferrous alloys, copper-beryllium, copper - beryllium - nickel alloys. The BCIRA production of double-strength gray cast iron by bringing about formation of nodular graphite. A full discussion treats the subject of "Ceramals," the combination of metals and ceramics for high temperature use. Techniques include adding of oxides and intermetallic compounds to metals, bonding more metals such as borides, carbides, and oxides with pure metals and single-phase alloys, and preparation of a porous ceramic compact into which molten metal is infiltrated. Alfred University has undertaken a fundamental study of reactions between certain metals and ceramic oxides and carbides at high temperatures in oxidizing atmospheres. Combinations of silicon, cobalt, chromium, nickel, iron, tungsten, and molybdenum with alumina, silica, magnesia, zirconia, beryllia, chromic oxide, and cobalt oxide are under investigation. In addition to this Navy project, two studies have been made in the N. Y. State College of Ceramics to investigate properties obtained by combining ceramics and metals. Silicon carbide aluminum oxide, fire clay grog, and whiteware grog, in finely divided condition, were combined with powdered copper, nickel, iron, silicon and aluminum. The interesting results are being investigated further.—INCO.

Metal Conservation in Europe: Progress of Phosphating. *Metallurgia*, 37, No. 218, 105-106, (1947).

A review of war-time developments in phosphating technique in Germany, Italy and Russia.—MA.

The Prevention of Metallic Corrosion. G. Fitzgerald-Lee, *The Aeroplane*, 73, No. 1890, 251-253 (1947) Aug. 29.

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An analysis of the causes that underly the corrosion of materials showing that the main factors affecting the corrosion of a metal are its composition and physical condition. Methods of corrosion prevention are classified as physical, chemical and electrolytic. In the first method, the grain structure of the metal is altered or coating of a foreign material is used. The other two methods deposit, thicken or intensify an oxide or salt film on surface. Thirty methods of corrosion prevention are mentioned. Cadmium plating is the best process for the treatment of steel parts and is widely used for aero-engine cylinder barrels, valve springs, studs, nuts, etc. The Bengough-Stuart anodizing process is the best process for aluminum and its alloys. Anodizing is better for wrought than for cast alloys, because differences in grain-size of the castings cause variations in the thickness of the film. Chromate pickling is particularly used for magnesium alloy castings. Bengough has originated a bath containing selenium dioxide and sodium chloride for the treatment of magnesium alloys to specifications D.T.D. 59A, 88B, 136A, and 259.—AER.

INHIBITORS

Systematic Investigation of Corrosion Inhibitors. de Decker, Amsterdam, Holland, Paper before *Journées Metallurgiques d'Automne, Fall Metallurg. Conf.*, sponsored by Soc. Française de Métallurgie and Comm. Tech. des états de surface, Paris, Oct. 6-10, 1947. (Abst. in French.)

The determination of general superficial corrosion as a function of the concentration is accomplished by means of curves whose slopes furnish information on the behavior of inhibitors. Next the amplitude of corrosion is determined with the aid of Wachter diagrams. The importance of pits is considered from the point of view of their number and depth. Local attack which is produced at the line of separation of liquid and air on partially immersed samples requires special tests.—INCO.

INSPECTION

Measurement of Thickness of Oxide Coatings on Aluminum Alloys. R. B. Mason & W. C. Cochran, *ASTM Bull.*, No. 148, 47-51 (1947) Oct.

Makes use of the Filmeter, which is a portable battery-operated electronic beat-frequency oscillator for rapid measurement of the thickness of oxide coatings. Method is investigated and compared with the results obtainable by microscopy

or stripping. It is concluded that the Filmeter is a useful means of checking thickness and uniformity of oxide coatings without destruction. It can also be used for rough measurement of conductivity and in some cases for approximate identification of aluminum alloys.—BNF.

First Progress Report on Non-Destructive Testing of Drill Pipe. L. R. Jackson & others, *Drilling Contr.*, 4, 54-55, 72 (1947) Dec. 15.

American Association of Oilwell Drilling Contractors has authorized Battelle Memorial Institute to conduct an investigation of methods for nondestructive testing of oilwell drill pipe. The facilities and research program are outlined in this report.—MA.

Electronic Methods of Inspection of Metals. H. F. Hamburg, J. L. Saunderson, R. S. Segsworth, E. O. Dixon, C. M. Lichy, C. S. Barrett & H. T. Clark. A series of seven educational lectures on electronic methods of inspection of metals, presented to members of the ASM during the 28th National Metal Congress and Exposition, Atlantic City, November 18-22, 1946. Med. 8vo. Pp. iii+189, illustrated. 1947. American Society for Metals, 7301 Euclid Ave., Cleveland, (\$3.50).

Contents: H. F. Hamburg, "Electronic Methods for the Measurement of Strain in Metals;" J. L. Saunderson, "Spectrochemical Analysis of Metals and Alloys by Direct Intensity Measurement Methods;" R. S. Segsworth, "Uses of the Du Mont Cyclograph for Testing Metals;" E. O. Dixon, "Supersonic Methods of Metal Inspection;" C. M. Lichy, "Determination of Seams in Steel by Magnetic-Analysis Equipment;" C. S. Barrett, "The Electron Microscope and Its Application to Metals;" H. T. Clark, "Electronics in Liquid Steel."

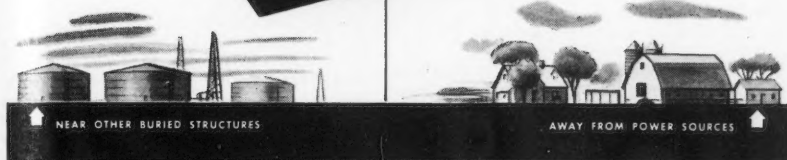
METAL FAILURE

Influence of Copper Concentration on the Corrosion-Resistance of Aluminum-Magnesium-Silicon and Aluminum-Magnesium Malleable Alloys. H. J. Seemann & K. Wesch, *Korros. u. Metallschutz*, 16, 256-259 (1940); *Brit. Absts.* B1, 170 (1947) May.

Aluminum alloys containing (I) 0.8-0.9% magnesium, 1% silicon, 0.75% manganese, 0.2-0.3% iron, 0-0.5% copper and (II) 7% magnesium, 0.3% manganese, 0.12-0.25% silicon, 0.3% iron, 0-0.5% copper were tested. (I) was quenched from 520° and aged either at 175° or at room temperature and (II) was quenched from 380° (homogenized), slowly cooled from 380° (slightly heterogenized), or slowly

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SURFACE TREATMENT

Anodic Oxidation of Aluminum Alloys and the Possibilities of Its Application in Machine Building. N. D. Tomashov *Vestn. Inzh. Tekhn.*, (In Russian) No. 2, 59-65 (1946); *Chem. Abstr.*, 40, 6005 (1946).

The electrolytes used for anodic oxidation are divided roughly into three groups: (1) electrolytes which have no effect on the freshly formed oxide film (solutions of nitrates, bicarbonates, borates, phosphates, and chromates); (2) electrolytes which slightly dissolve the film (chromic, oxalic, and sulfuric acids, bisulfates, alums, and permanganates); (3) electrolytes which readily dissolve the film (alkali hydroxides, hydrochloric acid, and chlorides). The thickness and the density of the oxide film are largely determined by the electrolyte in which it is formed. Films of appreciable thickness (1-100 and in

certain cases up to 600 μ) can be produced in electrolytes of group (2) by properly choosing the concentration, temp., e.d., nature of current (A.C. or D.C., potential, etc.), time of anodizing, etc. The effects of these factors, individually and combined, are discussed. Anodically oxidized aluminum has properties which make it desirable in the construction of internal-combustion motors. For this purpose, oxidized films 50-500 μ thick are required. The films are porous to an extent variable within certain limits. The pores can be filled with chromates to impart corrosion-resistance. They can also be filled with pigments to color the surface, with silver salt to photo-sensitize it, or with oil or colloidal graphite to impart anti-friction properties to the surface. The oxidized film adheres very strongly to the aluminum base. The alumina film is resistant to high temperature, very hard, wear-resistant, its heat condition is established to be 0.001-0.003 cal./cm. sec., and its coefficient of heat reflection at 150°-200° C. is 80 compared with 100 for a black body. The advantages of using alumina films on pistons, cylinder heads, cylinder linings, bearings, and other parts are discussed.—MA.

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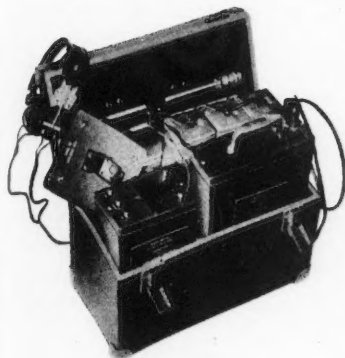
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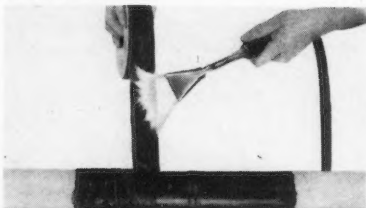
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TESTING

Method of Test for Permeability to Moisture of Organic Surface Coatings. *Paint & Varn. Prod. Manager*, 27, 273-274 (1947) Oct.

Federation Standard 9-47 is presented by the Standards and Methods of Test Committee.—BLR.

WATER CORROSION

Corrosion of Hot Water Storage Heaters. Chris Goldkamp, *Gas*, 22, No. 2, 33-35 (1946); C. Abs., 40, No. 8, 2098 (1946).

An important cause of corrosion is galvanic couples, caused by the use of galvanized tanks with water pipes and intake pipes of copper. Local corrosion can be caused by defects in the galvanizing and by lead in the coating. Corrosion occurs rapidly if the salt concentration of the water is high, and increases rapidly with temp., the rate of corrosion being twice as great at 180° F (82° C) as at 140° F (60° C). Other minor causes are listed. The use of non-ferrous metals throughout the tanks and piping would solve the problem; vitreous enamel and plastic coatings might be effective.—MA.

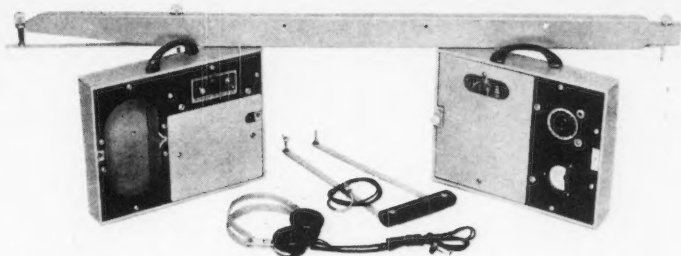
A Review of the Basic Principles of Corrosion Control by the Use of Lime. E. S. Hopkins, Paper before TAPPI Convention, New York, Feb. 23, 1948; *Paper Trade J.*, 126, No. 8, 56 (1948) Feb. 19.

Basic principles showing corrosion of iron and steel water pipe as function of the dissolved oxygen are reviewed. Neutralization of free carbon dioxide in low alkaline water by lime and the subsequent precipitation of a calcium carbonate free oxide coating on pipe surfaces retards corrosion to the point of practical elimination. A water so treated is stable when maintained at the calcium carbonate saturation point. Cost of treatment given.—INCO.

External Deposits on Boiler Heating Surfaces. Anon., *Combustion*, 18, 26-28 (1947) May.

A digest of a report issued by the British Boiler Availability Committee covering an investigation of the form and composition of deposits in a large number of boilers examined. The mechanism of deposit formation was investigated and is discussed; and the behavior of sulfates, bisulfates, phosphates and chlorides was studied, particularly chemical changes taking place in the vapor phase.—BLR.

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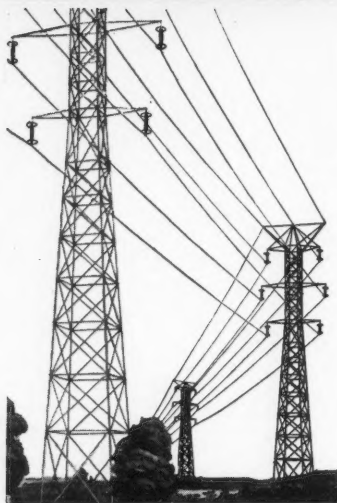
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Index to Advertisers

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| | |
|--|--------------------|
| Allied Chemical & Dye Corporation, Barrett Division | 8 |
| Aluminum Company of America (Alcoa) | 29 |
| American Cast Iron Pipe Co. (Acipco) | 31 |
| American Hot Dip Galvanizers Association | 34 |
| American Pipe & Construction Company (Amercoat) | 15 |
| Bechtel Corp. & H. C. Price Co. (Somastic) | 21 |
| Cathodic Servicing Company | 25 |
| Crutcher-Rolfs-Cummings | Inside Back Cover |
| Dearborn Chemical Company | Inside Front Cover |
| Dixie Tank & Bridge Company | 33 |
| Dow Chemical Company, The, Magnesium Division | 36 |
| Electro Rust-Proofing Corporation (N. J.) | 30 |
| General Paint Hill-Hubbell & Co., Division | x |
| Humble Oil & Refining Co. (Rust-Ban) | 27 |
| International Nickel Co., Inc., The | iv-v |
| Johns-Manville | ii |
| Koppers Company | ix-35 |
| Maloney, F. H., Company | 11 |
| Mayes Bros, Inc. | i |
| Midwestern Engine & Equipment Company, Inc. | vii |
| Motorola, Inc. | 19 |
| Natasco Company, The | 23 |
| Nilsson Electrical Laboratory, Inc. | 31 |
| Perrault Bros., Inc. (Glasfloss) | 13 |
| Reilly Tar & Chemical Corporation | 17 |
| Stearns, D. E. | Back Cover |
| Tapecoat Company, The | 32 |
| Westinghouse | viii |
| Wilkinson Products Co. | 33 |

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